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Copyediting by
Marianne Brokaw
Houghton, Michigan

Composition by
Morgan Printing
Austin, Texas

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Printed in the United States of America

ISSN 0440-9213

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Volume 40, No. 3   2006

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 Archaeological scholarship evolves, which means even the most progressive research is fleeting. Accordingly, the history of archaeology is riddled with innovative ways of explaining the past, and multiple, viable lines of interpretation can be pursued for any given archaeological site. In this intellectual climate, the array of interpretive possibilities and research directions in historical archaeology appear to be blossoming; however, the humanistic directions seem risky, at times idiosyncratic, and occasionally in need of scientific explanations (Delle 1999:136; Cleland 2001a:7, 2001b:30).

Incorporating forensic techniques and tests into research allows archaeologists to verify otherwise tentative interpretations and create tangible links among people, places, and things. The application of forensic technology to archaeological problems has already demonstrated that anthropologists can prove some of their interpretations beyond a reasonable doubt (Connor and Scott 2001). Today archaeologists can apply myriad forensic techniques to their work to answer questions and test hypotheses. In addition to standard skeletal analysis, archaeologists can recover nuclear and mitochondrial deoxyribonucleic acid (DNA) from artifacts and human remains, locate buried anomalies with remote sensing technology, and view artifacts spatially and microscopically to re-create historical events. This volume also demonstrates the successful expansion of the study of old and degraded DNA recovered from organic remains and visible stains, familiar to biological anthropologists as ancient DNA (aDNA), to include studies on DNA recovered from historic period personal artifacts. Julie Schablitsky (this volume) introduces the specialization of genetic archaeology, which is devoted to the recovery and analysis of DNA from artifacts, and its creative application to archaeological sites by incorporating DNA results with documents, material culture, and site structure. In order to launch genetic archaeology’s application to historical sites, this prelude provides a brief overview of human DNA, along with its extraction and recovery techniques, before introducing the articles contained herein.

**Nuclear DNA and Mitochondrial DNA**

The human genome consists of nuclear and mitochondrial DNA. Nuclear DNA is present in 23 pairs of chromosomes within the nucleus of each cell, with a paternal and maternal chromosome inherited from each parent. Sex cells (sperm and eggs), contain only a single genome copy that consists of a recombined patchwork of genes of both paternal and maternal origin. Archaeologists and other research scientists use genomic nuclear DNA to reveal a person’s sex, allelic profile, and rare allele variants in skeletal and now artifactual samples. In addition, nuclear DNA provides information that makes it possible to determine the number, the sex, and possibly the ancestral origins of people who came into contact with a particular artifact. Limitations of nuclear DNA include its short shelf life, having just two copies per cell, and the difficulty in showing direct ancestor/descendant relationships over many generations.

Although nuclear DNA exists in the nucleus of the cell, DNA containing different genetic information can also be found within a cell’s mitochondria. As few as one or as many as several hundred mitochondria may exist within each cell. Mitochondrial DNA (mtDNA) is solely inherited from one’s mother. Sperm contain mitochondria, but only the female’s egg—with rare exceptions—contributes mitochondria to the new individual. Since copies of genetic information are stored in each mitochondrion, scientists have a better chance of recovering intact mtDNA than nuclear DNA with just two copies in the nucleus. In consideration of this fact, studies of ancient mtDNA have met with greater success, and consequently biological anthropologists focus their research on the
extraction of mtDNA rather than nuclear DNA from ancient organics (Herrmann and Hummel 1994:3).

Historical archaeologists have an advantage over their prehistorian colleagues in human DNA recovery. By definition, the material studied by historical archaeologists is less ancient, thereby decreasing the number of times artifacts encounter temperature fluctuations and exposure to moisture between the moments of deposition and recovery. An additional benefit of working with the recent past is the relatively easy access to and availability of living descendant communities that can readily provide referential information for mtDNA analysis.

DNA from Archaeological Contexts

Following the advances of their colleagues in molecular biology, bioarchaeologists have been extracting degraded DNA for the last two decades (Herrmann and Hummel 1994; Jones 2001:14). The “molecular blueprint” for all life on earth can survive in fragments on archaeological sites (Jones 2001:10). DNA begins to degrade rapidly after cell death occurs, unless physical and/or biological processes such as freezing or desiccation intervene to maintain the physical integrity of the DNA-containing materials (Handt et al. 1994; Monsalve et al. 2002). For the most part, DNA is vulnerable to environmental conditions such as ultraviolet radiation, moisture, temperature fluctuations, and soil acidity. Although aged DNA breaks down over time, scientists have successfully recovered DNA from human bone thousands of years old (Herrmann and Hummel 1994:1–3) and from personal artifacts older than 125 years (Dixon this volume; Schablitsky this volume). Archaeologists should be encouraged and excited by the potential of forensic applications to their sites and materials, but caution must always be exercised when merging scientific disciplines.

Contamination

Contamination of DNA samples can be detrimental to a researcher’s results. Although contamination can occur in both the field and laboratory, it is possible for archaeologists to protect their samples by taking certain precautions. In order to reduce the chances of contaminating artifacts and organic material, it is first necessary to anticipate the potential for contaminants at the site. Field personnel should be taught to identify potential candidates for DNA testing and how to protect samples from contamination. Since the recovery of DNA from artifacts is only in its infancy, scientists are continuing to learn the environments, materials, and contexts that allow DNA to survive in archaeological contexts. A simple and effective rule is to treat any personal artifact that potentially came into contact with human body fluids or was inserted into an orifice as a potential carrier of human DNA. Examples of personal artifacts include pipe stems, mouthpieces from musical instruments, irrigators, syringes, and false teeth.

It is also important to have on hand a sterile DNA sample kit that includes paper envelopes and bags, forceps, writing utensils, latex gloves, and face masks. One person on the site should be responsible for the recovery of the artifacts, thereby eliminating multiple potential contaminant contributors. Recovery of several artifacts requires new gloves and forceps for each artifact, regardless of contextual association. Additional precautions include collection of DNA samples from all archaeologists who may have come into contact with the objects. If the forensic laboratory personnel suspect contamination of a sample, the archaeologists can be quickly eliminated as contributors through the analysis of a simple cheek swab.

In addition to contamination of the sample through handling by archaeologists or forensic laboratory personnel, samples can be cross contaminated or contaminated by chemicals and carryover by laboratory products used to identify degraded or altered DNA (Hummel 2003:133). Although archaeologists have little control over the latter two, they can help reduce sample contamination by choosing a DNA laboratory that meets forensic investigation standards. The elimination of cross contamination is accomplished by ensuring that the laboratory handles artifact samples separately and adheres to strict “DNA clean” procedures for all equipment. Typically, forensic laboratories eliminate chemical and product carry over by separating the pre- and postamplification equipment in separate rooms (Hummel 2003:133). The final way to ensure credibility of the recovery
of degraded DNA is to repeat the experiment, preferably by different personnel or in a different laboratory, or both.

**STR and PCR: Breaking Down DNA**

Preservation, degradation, and diagenesis inevitably affect and may transform DNA, making its recovery much more difficult than the extraction of DNA from living organisms (Herrmann and Hummel 1994:1–2). Despite this challenge, archaeologists should not be discouraged since degraded forms of DNA can be resuscitated.

Today’s procedures extract, amplify, and profile **residual DNA** from historic objects. Using short tandem repeat (STR) analysis, it is possible to determine the sex, genetic profile, and the number of individuals in contact with an artifact. STRs are polymorphic DNA loci, or areas on the chromosome, that contain a repeated nucleotide sequence. The number of repeat units at an STR locus is highly variable, and many loci are known. The repeating unit is usually from two to seven nucleotides in length. Often referred to as the building blocks of DNA, the four nucleotides are the variable units in the nucleic acid chain, and the sequence in which they occur is the basis of genetic similarity and difference (Rudin and Inman 2001:211). Such polymorphic STR loci are therefore very useful for human identification purposes (Edwards et al. 1992). For example, STRs allow the identification of particular alleles at certain loci on the chromosome, which helps determine the number of individuals, sex, and perhaps population group affiliated with a particular sample.

In order to extract such data from DNA molecules, forensic scientists amplify the STR loci using the polymerase chain reaction (PCR) process. During the middle 1980s, the invention of the PCR technique provided a means of identifying degraded or altered DNA (Mullis and Faloona 1987; Herrmann and Hummel 1994:8; Jones 2001:17–18). The family of DNA polymerase enzymes plays a crucial role in replication and repair of damaged double helices in living, growing organisms by copying single strands of DNA to make double-stranded DNA. Once this enzyme’s DNA replication duties were harnessed, it became possible to amplify tiny, incomplete fragments of genetic material, such as samples from archaeological contexts, because the PCR technique only required traces of the original nucleic acid to produce the numerous copies required to achieve accurate genotyping analysis. Additionally, PCR-based tests have now been standardized and automated to meet criminal forensic standards, ensuring reproducible results (PE Applied Biosystems 1998).

**Race vs Ancestry**

A well-preserved DNA sample can yield a series of alleles at known loci on the chromosome and, in turn, identify a person on the basis of his/her unique combination. In the last several years, forensic scientists have begun to examine DNA databases to determine whether frequencies of alleles or rare allele variants at known loci on the chromosome are associated with certain population groups (Budowle et al. 1999; Budowle et al. 2001), which include traditional, albeit problematic, categories such as African American, Asian, Caucasian, Hispanic, and Native American. Although described as “population groups,” such categories clearly refer to the race concept. It is important to realize that ambiguous terms such as race crudely categorize the reality of human culture and genetic diversity and should be used with caution (American Anthropological Association 1999; Brace and Seguchi 2002).

Despite the shortcomings of the term, forensic scientists continue to rely on racial identities in the national DNA databanks used to assist with crime investigation. Although the genetic variation within traditional conceived races is much greater than that between them, differences exist in the frequencies with which certain genetic variants occur in populations of differing biogeographic ancestry (Bamshad et al. 2003).

Since its invalidity as an absolute category is guilty as charged, the race concept, along with its loaded implications, clearly remains a category of tremendous significance for historical archaeologists and forensic scientists alike (Mays 1998; Rhine 1998; Orser 1999, 2001). Research on population groups continually inspires questions about the ancestral origins of people who used artifacts unearthed by archaeologists. In some cases, an artifact harboring genetic material with identifiable rare allele variants may provide molecular data that point to the ancestral
background of someone who came into contact with that object (Schablitsky, this volume).

While this discussion of the race concept and its association with forensic studies may raise some concerns, it is not an attempt to legitimize that concept. Rather, it offers one part of a complex solution to pan-anthropological efforts to purge the race concept. Through both the acknowledgment and condemnation of the socially constructed term, archaeologists, along with forensic and genetic anthropologists, can begin to educate a broad audience by substituting the term ancestry for race. Reference to a person’s or group’s ancestry allows anthropologists to use a descriptor that recognizes genetic and cultural differences expressed by individuals throughout the world.

**Article Summaries**

The first set of articles within this volume underscore the utility of nuclear and mitochondrial DNA tests at historical archaeological sites. The extraction and interpretation of nuclear DNA from personal artifacts introduced historical archaeologists to the new specialty of genetic archaeology. Julie Schablitsky describes various forensic tests on a glass hypodermic syringe and associated needles unearthed from a 19th-century home in the mining West. Using all applicable forensic technology available in the laboratory, the syringe underwent DNA extraction procedures and a gas chromatograph mass spectrometer (GC/MS) test for opiates. By interpreting the archaeological site in conjunction with DNA results, she demonstrates how genetic information altered preliminary artifact associations and illuminated a previously unrealized past.

Exploring the applicability of genetic archaeology to different sites and artifacts, Kelly J. Dixon’s article overviews the ways in which the GC/MS and genetic analyzer retrieved biological evidence from artifacts recovered from the ruins of a 19th-century African American saloon in a northern Nevada boomtown. The GC/MS results identified leftovers from a meal, a discovery that reminds archaeologists to be wary of cleaning certain artifacts, as they may contain microscopic information that can deepen understandings of material data. DNA tests on a tobacco pipe stem demonstrated that it is possible to determine whether a man or a woman used an otherwise genderless artifact. This, Dixon argues, is grounds for making more meaningful, gender-based interpretations that are based soundly upon unequivocal, forensic evidence.

While Schablitsky and Dixon concentrate on the retrieval of nuclear DNA from artifacts, Mark D. Leney’s essay focuses on the recovery of mtDNA from bones and teeth using human remains associated with forensic archaeological casework from various parts of the world and from a range of environments. Leney describes which parts of the human body are most conducive for the recovery of mtDNA and discusses ways to avoid contamination of the bone samples. This invaluable study of historical skeletal material in various environments will no doubt direct the collection of future DNA samples.

Douglas W. Owsley, Brooks B. Ellwood, and Terry Melton combine traditional crime scene investigation using remote sensing, archaeological methods, human osteology, and mtDNA testing to locate and identify the 125-year-old skeleton of Texas gunslinger William Preston Longley. The article first introduces readers to the complicated process of locating an unmarked grave and then determining from skeletal remains the sex, age, and stature of the individual in question. The authors also effectively incorporate material and historic records, such as the report of a corsage made of celluloid attached to the lapel of the infamous gunslinger, to assist identification of the purported remains. The scientific team takes the identification one step further by successfully matching the outlaw’s mtDNA with a living maternal relative, which ultimately closed the case.

Ground-penetrating radar (GPR) is fast becoming a popular, innovative tool for forensic and archaeological fieldwork. Much of its popularity lies in the fact that it provides a nondestructive means of scanning the subsurface of a site or scene. Lawrence B. Conyers demonstrates how, in addition to GPR’s ability to demarcate buried features such as building ruins, it is especially useful in locating unmarked graves.

Although archaeologists are encouraged to apply remote sensing techniques prior to excavating individual burials, occasionally rescue-and-recovery projects do not require the technology for the exhumation of an entire cemetery. William D. Stevens and Jonathan M. Leader’s article discusses the analysis of 40 Civil War
era burials, including the first crew of the H.L. Hunley submarine, recovered from beneath the Citadel’s Johnson-Hagood Stadium. Osteological analysis revealed skeletal and dental lesions on the remains, shedding light on the sailors’ lives and the physical labor they endured while in service. In addition, Stevens and Leader’s work can serve as a comparative study for future osteological work associated with individuals from the Civil War era.

The discovery and exhumation of Isaac Newton Mason, a Civil War confederate soldier, provides archaeologists a step-by-step protocol for the study of human remains preserved in cast-iron coffins. Owsley and experts in the historical, archaeological, and forensic fields joined forces to determine the class status, occupation, diet, and vices of Private Mason. In addition to artifact, clothing, historical, and osteological analysis, the team also conducted stable carbon and nitrogen isotope analysis on the bone, radioimmunoassay tests on the hair, and toxicology studies. Results from this collaborative research not only provide a glimpse into a southern soldier’s lifestyle but also offer a view into the trials and travails of transporting deceased family members to their homes after battle.

While some scientists concentrate on how people lived, Thomas A. Crist’s research focuses on how people died. Zeroing in on bone damage to illuminate differences between postmortem damage and bullet wounds, he ultimately challenges previous findings on early-19th-century gun culture. Specifically, Crist compares historic documentation on trauma to minorities with secondary histories of gun possession. He subsequently encounters obvious contradictions between one historian’s views about the gun culture and archaeologists’ frequent encounters with bone damage from bullet wounds. Crist’s findings boldly underscore the necessity of using archaeological data in concert with historic documents to accurately interpret the past.

Moving from bullet wounds to the weapons fired to inflict such injuries, Kent P. Weber and Douglass D. Scott study microscopically the subtle markings on percussion caps to trace the progression of an historic battle. Treating the battlefield as a crime scene, Weber and Scott reproduce and analyze percussion caps to identify the number, type, and movement of weapons, ultimately re-creating an historic event. In order to encourage other archaeologists to apply this same innovative approach, the authors test and verify their findings using the percussion-cap identification method on an unknown collection, proving its fail-safe applicability to other archaeological sites.

**Just Ask the Question**

Forensic science often calls upon archaeology to establish proper provenience and standards of evidence recovery from crime scenes. While archaeologists help and even participate in such investigations, they do not tend to apply forensic methods to archaeological sites as much as they could—and should. An interdisciplinary, reciprocal potential exists for these two disciplines to prosper in tandem. The diverse studies displayed in this volume provide examples of proven scientific and biomedical methods and techniques available to archaeologists.

Over the last decade, forensic applications in many scientific fields have advanced DNA research, lowered laboratory costs, and raised standards (Handt et al. 1994). With the growth of such technologies comes a certain inflexibility that could frustrate archaeologists. For example, most forensic applications are focused largely on individuation of human remains or human residues. Instead, archaeologists may be more interested in answering questions about nonhuman biological materials, such as foodstuffs, artifacts, or commensal species. As archaeologists become increasingly familiar with the fundamental technologies involved, they will likely find that variations and modifications of certain forensic techniques will adequately address archaeological questions in ways that the molecular biologists have not yet conceived. It is, then, up to archaeologists to raise questions that inspire experimentation and innovation related to the recovery of DNA. The application of forensic technology to historic sites will drive forward the development of molecular archaeology while helping reduce the ambiguous interpretations that too often plague historical archaeology.

While forensic anthropology is driven by questions posed by the legal system, historical archaeology is driven by a variety of research
questions, many of which center upon producing a humanistic understanding of the past. In addition to historical records and physical remains, the recovery of biological evidence from the archaeological record provides yet another dataset for archaeologists. Each of the studies outlined herein is testament to the diversity of techniques available to forensic scientists and now to historical archaeologists.

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Genetic Archaeology: The Recovery and Interpretation of Nuclear DNA from a Nineteenth-Century Hypodermic Syringe

ABSTRACT

Archaeologists recovered a hard rubber urethral irrigator, glass hypodermic syringe, and six associated copper-alloy needles beneath the charred remains of a small 19th-century home in Virginia City, Nevada. In order to interpret the function and context of the medical paraphernalia, the artifacts were submitted to a forensic laboratory in hopes of recovering historical genomic nuclear human deoxyribonucleic acid and to identify drug residue from the glass syringe using a gas chromatograph mass spectrometer (GC/MS). Some of the medical artifacts tested positive for drug residue and human nuclear DNA, thereby demonstrating the ability to successfully obtain chemical and genetic information from artifacts more than 125 years in age. The findings and interpretations illustrate the innovative research potential awaiting archaeologists in the new specialty of genetic archaeology.

Introduction

During the investigation of a Virginia City, Nevada, neighborhood, located between the red-light district and Chinatown, Portland State University, Oregon, and University of Nevada, Reno, archaeologists discovered the remains of a small, 19th-century dwelling at 18 North G Street. The house, measuring approximately 12 x 16 ft., sat in a densely occupied residential neighborhood that experienced short-lived business ventures, an occasional brothel, a German clinic, and a Black church (Figures 1, 2). The ethnically heterogeneous neighborhood included Europeans, Americans of European and African ancestry, Jamaicans, and Chinese. Most of the residents were transient families and single men employed in the local gold and silver mining economy.

Very few records document the history of the homes and businesses in the neighborhood; however, the Virginia City Land Deeds (1868) book listed buildings on the lot in 1867. City directories suggest settlement in the neighborhood as early as 1862 (Virginia City Directory [VCD])...
The structure at 18 North G Street likely housed several renters throughout its short history between the mid- to late 1860s through October 1875. For that reason, archaeologists found it difficult to associate many of the artifacts with individual occupants. The address first appeared in the 1873–1874 city directory as a dressmaker shop operated by Mrs. M. A. Andrews, who was a member of the Daughters of Temperance Society (Territorial Enterprise 1873c). Mrs. Andrews worked out of her shop on G Street, but she lived at 136 North D Street with her husband, Fred (VCD 1873–1874). Based on building size and lack of documentary evidence to suggest otherwise, it is unlikely anyone lived at this location during the time it served as a dressmaker shop. On 4 July 1873, Mrs. Andrews died at 35 years of age (Territorial Enterprise 1873c). Given the shortage of affordable housing in Virginia City, new tenants likely moved into 18 North G Street immediately (Territorial Enterprise 1874b).

Although the building’s use is unknown for a brief period after Mrs. Andrews’s passing, a British family occupied the house by 1875. The crowded dwelling housed Thomas Cooper who worked as a miner and his wife, Eunice; two young daughters, Evelyn, age 10, and Ida, age 8; and their 5-year-old son, George (Nevada State Census 1875; VCD 1875). In October 1875, this humble dwelling burned in a large fire that claimed central Virginia City. The Coopers apparently did not reconstruct their G Street house, and the empty lot and surrounding ruins fell into disuse.

Almost 125 years after fire consumed the home, archaeologists excavated and screened through the charred remains of the dwelling house (Schablitsky 2002). Excavators collected artifacts commonly associated with household activities and dressmaking, including glass, ceramics, buttons, beads, and straight pins. They also discovered a hard rubber urethral irrigator (Figure 3). Victims of venereal disease as well

FIGURE 3. Urethral irrigator, used to treat venereal disease, found under floorboards. (Photo by author.)
as doctors purchased these instruments to relieve and treat unpleasant symptoms of gonorrhea and syphilis (Goodenough 1904:375). Within one meter of the irrigator, archaeologists found a glass syringe. The glass hypodermic syringe still retained its rolled copper needle and rested beneath the floorboards on top of a soil terrace created during the construction of the building. Prior to October 1875, one of the occupants likely stored or discarded the syringe beneath the floorboards. This uncalibrated syringe is approximately 6 in. long and 7/16 in. wide. The open end of the syringe is rimmed in lead, while the point contains a rolled copper needle. The glass piston, with fragments of leather packing adhering to one end, is 4-1/2 in. long (Figure 4). The primitive construction of this syringe is similar in design to the Ferguson syringe introduced in 1856. Medical manufacturers fashioned this prototype from colorless glass and added leather packing to the end of the syringe piston. These early hypodermic syringes were far from perfect, and physicians often complained about the design, including the inability to accurately measure solutions into the ungraduated glass barrel (Howard-Jones 1947:211,215). By the early 1880s, medical companies actively improved medical equipment by manufacturing hypodermic syringes out of glass, hard rubber, celluloid, German silver, pure silver, and gold (Bartholow 1882:37).

Within the front of the home and in close proximity to the syringe, archaeologists recovered six used hypodermic syringe needles. These copper alloy needles were 5/8 in. long with a diameter of 1/16 in. Microscopic observation revealed three small perforations along their length. These holes may have served to ventilate and thereby prevent the growth of mildew that ultimately clogged historic period needles. One of the needles also exhibits evidence of sharpening in one location, thereby improving the dull point and reducing the relatively large size of the needle. To facilitate injection, the early hypodermic syringe user or administrator commonly lanced the skin with a lancet or trocar prior to inserting the needle. These early hollow needles penetrated the

FIGURE 4. Early hypodermic glass syringe with copper alloy needle. (Photo by author.)
skin with difficulty and caused pain. In 1865, Charles Hunter improved the syringe by “putting a cutting point on the canula for transfixing the skin” (Bartholow 1882:36). The needles recovered from the home do exhibit a cutting point; however, sharpening likely facilitated insertion and decreased pain during injections.

The physician’s syringe improved drastically over time, but new models were too expensive for the general public. Consequently, pharmacists stocked many inexpensive and poorly made versions similar to the Ferguson syringe through the 1870s (Howard-Jones 1947:218). Hypodermic syringe technology and history, site occupation, and the 1875 fire collectively indicate that the Virginia City syringe was an inexpensive instrument, mass-produced between the mid-1860s and 1875.

**Forensic Potential**

Forensic technologies, such as the GC/MS and genetic analyzer, solve mysteries daily in criminal cases throughout the world. Forensic scientists primarily use the GC/MS to determine the chemical composition of unknown substances recovered from crime scenes or criminal suspects. They also commonly swab clothing, weapons, and other items harboring blood, semen, sweat, and saliva for modern DNA testing. Forensic laboratories use a highly advanced genetic analyzer to identify the number of people associated with a forensic sample, including the contributor’s sex and allelic profile.

As a result of GC/MS technology and the increased sensitivity of DNA testing, archaeologists now have access to these same forensic tools. The GC/MS gives archaeologists the ability to determine the chemical composition of drugs contained in medicine bottles or syringes and to identify other unknown substances recovered from archaeological sites (Espenshade 2001; Dixon 2002; Schablitsky 2002). Through nuclear DNA testing, scientists can retrieve human DNA profiles that are at least 125 years old, thereby revealing the number of people associated with an artifact, the sex, and, possibly, the population group of the person who came into contact with an item. In this case, recovering genetic information could potentially include or exclude the Cooper family or Mrs. Andrews as the syringe user. Since the history of the people who occupied the small home was important in understanding the social, ethnic, and class composition of this residential neighborhood, forensic tests attempted to find out who used the syringe, the reasons behind the injections, and the type of medicine injected into the recipient.

**Nuclear DNA Methods**

The urethral irrigator, syringe, and associated needles from 18 North G Street were submitted to a forensic laboratory in hopes of revealing the number of people, the sex, and possible population group of the syringe user(s). Raymond A. Grimsbo, forensic scientist at Intermountain Forensic Laboratories, Inc., agreed to examine the drug paraphernalia recovered from the archaeological site. Two of the six needles were badly damaged and charred from the house fire; therefore, technicians excluded these needles from nuclear DNA testing. Grimsbo tested four of the six loose needles for historical human DNA. In addition to four loose needles, the laboratory also performed nuclear DNA tests on the hard rubber urethral irrigator, the glass hypodermic syringe tip, and its associated copper needle.

After the preliminary nuclear DNA tests, Grimsbo successfully recovered DNA from the glass point of the syringe. Initially, all of the copper-alloy needles and the hard rubber urethral irrigator tested negative for human DNA. He interpreted the unsuccessful amplification of DNA as inhibition by copper remnants in the needle samples. In order to remove the copper inhibitors, Grimsbo extracted DNA from the needle samples using a modified Chelex process. Chelex is a resin that binds to metallic ions that inhibit the polymerase chain reaction.

After the addition of 5% Chelex, Grimsbo soaked the artifacts in as small amount of sterile water as possible and then placed the residue extracts in Centricon100® concentrators and incubated the samples. The Chelex successfully bound with the copper and allowed amplification of the DNA from two of the loose needles and the needle associated with the syringe. Grimsbo then repeated the process with the hard rubber urethral irrigator sample. Despite the introduction of Chelex into the sample, the laboratory
could not successfully recover DNA from the hard rubber urethral irrigator.

After identifying human DNA on four of the seven medical artifacts, the samples were submitted for additional testing to identify the sex and allelic profile. The next step included injecting the amplified products into a capillary on the ABI Prism® 310 Genetic Analyzer. GeneScan® software on a Power Macintosh G3 computer automatically analyzed the collected data, which was then imported into Genotyper® software for automatic genotyping of the alleles. This forensic laboratory test attempts to recover at least 2 alleles per person at 13 locations. Grimsbo also amplified the segment of the X-Y homologous gene amelogenin, which contains information on sex. Amplifying a segment of the amelogenin gene with a single primer pair is used for sex identification because different length products from the X and Y chromosomes are generated (Sullivan et al. 1993). When the results present an X without a Y, it does not necessarily exclude male DNA in the sample (Herrmann and Hummel 1994:209). The DNA extract may have been inhibited or degraded, thereby preventing an accurate expression of the sex. Archaeologists should be especially aware of this effect when interpreting severely degraded nuclear DNA from artifacts.

**Nuclear DNA Findings**

The forensic laboratory successfully extracted human DNA from two of the four loose needles, the glass syringe point, and the needle associated with the glass syringe (Table 1). Since contamination by the archaeology team and laboratory personnel is always a concern, Grimsbo tested everyone who came into contact with the artifacts and eliminated them as potential DNA contributors. An additional step taken to verify the validity of the results included repeating the tests three times. Further evidence of successful recovery of historical DNA included negative results on three of the artifacts from the same archaeological context. In other words, the combination of negative and positive results from the artifacts, along with repeated

<table>
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<th>Artifact</th>
<th>Sex</th>
<th>D3S1358</th>
<th>FGA</th>
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<td>X</td>
<td>12, 13, 14, 16, 17, 18</td>
<td>17, 18, 19, 20, 21, 22, 23, 24</td>
</tr>
<tr>
<td>Needle B</td>
<td>X,Y</td>
<td>8, 9, 11, 12, 13, 14, 15</td>
<td>25 (24.2, 26, 27)</td>
</tr>
<tr>
<td>Needle Associated with Syringe</td>
<td>X (Y)</td>
<td>15</td>
<td>30 (31)</td>
</tr>
<tr>
<td>Glass Syringe Point</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Artifact</td>
<td>D8S1179</td>
<td>D21S11</td>
<td>D18S51</td>
</tr>
<tr>
<td>Needle A</td>
<td>8</td>
<td>25 (24.2, 26, 27)</td>
<td>13</td>
</tr>
<tr>
<td>Needle B</td>
<td>9</td>
<td>30 (31)</td>
<td>15</td>
</tr>
<tr>
<td>Needle Associated with Syringe</td>
<td>11, (11, 6)</td>
<td>11, (9, 12, 13)</td>
<td>8</td>
</tr>
<tr>
<td>Glass Syringe Point</td>
<td>7</td>
<td>11, 9, 12, 13</td>
<td>8</td>
</tr>
<tr>
<td>Artifact</td>
<td>D7S820</td>
<td>D5S818</td>
<td>TPOX</td>
</tr>
<tr>
<td>Needle A</td>
<td>7</td>
<td>11, 9, 12, 13</td>
<td>8</td>
</tr>
<tr>
<td>Needle B</td>
<td>9</td>
<td></td>
<td>7</td>
</tr>
<tr>
<td>Needle Associated with Syringe</td>
<td>11</td>
<td>5</td>
<td>7</td>
</tr>
<tr>
<td>Glass Syringe Point</td>
<td>11 (9)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Table 1**

DNA RESULTS OF NEEDLES AND GLASS SYRINGE TIP
tests, indicates successful recovery of historical human DNA and not systematic contamination from contemporary sources.

Based on the relatively high number of positive results from the needles, copper material may help to preserve DNA. Copper is one of the freely occurring elements in nature and is the active ingredient in many organic preservatives. Microscopic observations of these needles show colorless glazing and green-blue salt formations. The salt formations act as a preservative, breaking down microorganisms in the soil, thereby limiting degradation of DNA. Archaeologists often observe preservation through contact with copper at their sites. For example, excavating a 19th-century copper stamp mill, Michigan archaeologists recovered intact 150-year-old textiles, leather, and wooden architectural features from native acidic soils mixed with cupreous sands (Dixon 1994:113). Archaeologists also found that organic materials in direct contact with copper can be preserved for more than 5,000 years (Martin 1999:158–159).

The four positive nuclear DNA samples from the syringe artifacts ranged from fairly intact to severely degraded. All of the alleles recovered from the samples were cross-analyzed against published databases on the relationship of STR loci and allele frequency among population or ancestral groups (Budowle et al. 1999:1277–1286; Budowle et al. 2001:453–489; Levedakou et al. 2001:736–761). The population groups are organized by a person’s self-affiliation of race. These databases contain allele frequencies for people of African descent (African Americans, Bahamians, and Jamaicans), U.S. and Canadian Caucasians, Hispanics, Chinese, and Native Americans. Forensic scientists often use these publications in the identification of humans in criminal cases. The databases were used to profile the DNA recovered from hypodermic needles as a means of associating rare allele variants with a particular ancestral group.

Needle A

The historical human DNA recovered from needle A was degraded. Genetic information from this sample yielded an X chromosome marker and an allele size of 13 at locus D18S51. When compared with population group databases, allele 13 is commonly represented in most ancestral groups (Budowle et al. 1999:1281). There may have been additional people who used this needle, but the number of users or their sex cannot be determined from the severely degraded sample. In other words, although an X chromosome marker represents females, the presence of a male user cannot be discounted since the genetic material that expresses the Y repeat unit may have disintegrated over time.

Needle B

The second needle contained both the X and Y repeat unit and multiple alleles at five different loci (Table 1). The presence of at least eight alleles at locus FGA and the X-Y expression suggest at least four individuals used this needle and at least one of the users was male. Most of the alleles in this DNA sample from the needle occur at regular frequencies in all populations in the databases, but three of the alleles are rare in the human population and occur primarily in populations of African descent (Table 2).

The database sample indicates that allele 12 at locus D3S1358 occurs most frequently in African ancestral groups (4.6%). Caucasians and Hispanics also manifest allele 12 but in lower numbers (2.9% and 1.3%). Allele 12 is absent in the database sample of Chinese and Native American populations. Allele 13 at locus D3S1358 is most prevalent in those of African descent, occurring in 7.3% of the population. Hispanic populations exhibit this allele at 3.8%, Caucasians at 2.5%, and Native Americans at 2.8%. This allele was not detected in the Chinese sample. Alleles smaller than 18 at locus FGA occur in populations of African descent 4.8% of the time. Native Americans exhibit this allele at 2.8%. This allele is very rare in Caucasian (0.5%), Hispanic (0.5%), and Chinese groups (0.81%).

Based on these forensic results, three rare allele variants, recovered from the copper alloy needle, occur more often in people of African descent than any other population group. Since there are four individuals represented on the needle, one cannot assume the three rare allele variants were contributed by the same person, but it is a possibility. The multiple lines of evidence, in this case three allele variants primarily associated with people of African descent and historical documentation of occupation of
the neighborhood by African Americans and Jamaicans, imply at least one person of African descent could have received a hypodermic injection of morphine at 18 North G Street. These interpretations are based upon the scientific findings that DNA in modern Americans of African descent is similar to historic period people of African descent. Although social pressure and laws prevented many interracial unions, sexual relationships did occur between European and African ancestral groups, leading to shared genetic markers in their children and descendants (Parra et al. 1998). As a result of inter-ancestral relationships, the allele frequency distributions of 19th-century African American and Jamaican populations may be closer to contemporary African Americans with shared genetic markers rather than to modern homogenous African populations.

The results do not eliminate Caucasians, Hispanics, Chinese, or Native Americans as additional genetic contributors. The other three sets of alleles on Needle B could not be attributed to a specific population group and may belong to either Caucasians, Hispanics, or people of African descent. Although the results do not eliminate Native Americans and Chinese as genetic contributors on the syringe needle, Virginia City history suggests they were unlikely users. The small population of northern Paiute Indians would have relied on traditional medicines (Hattori 1998:235; James 1998:156–157), and the Chinese would have turned to their physicians for medical treatment and to opium smoking, rather than to injection, for recreational opiate use (Territorial Enterprise 1873a).

**Needle and Glass Syringe Point**

The forensic laboratory also tested the needle and glass syringe point for DNA (Table 1). The results suggest the genetic material on the glass degraded over time. The only information gleaned from the glass syringe tip was the presence of an X chromosome. The severe degradation of the genetic information warns against concluding sex from this particular sample. It is important to note that amelogenin appears to resist degradation better than alleles. Further tests on degraded DNA are needed to determine if sex expression is the strongest and last genetic material to degrade on artifacts recovered from archaeological contexts.

The needle found in association with the glass syringe contained fairly intact human DNA. The STR results reveal at least one male and one female used the syringe. Grimsbo analyzed the results and noted the emphasized X marker or multiple X-specific variants along with the Y marker that he interpreted as human DNA from both a female and male. Between one and four alleles were identified at each of the nine different loci (Table 2). Based on the number of alleles at the locations, at least two people used this needle. The observed alleles are commonly represented in most populations

<table>
<thead>
<tr>
<th>Location</th>
<th>Allele</th>
<th>African Descent</th>
<th>Caucasian</th>
<th>Hispanic</th>
<th>Chinese</th>
<th>Native American</th>
</tr>
</thead>
<tbody>
<tr>
<td>D3S1358 12</td>
<td>Count</td>
<td>0.046</td>
<td>0.029</td>
<td>0.0133</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Frequency</td>
<td>4 to 5 out of 100</td>
<td>2 to 3 out of 100</td>
<td>1 to 2 out of 100</td>
<td>0 out of 100</td>
<td>0 out of 100</td>
</tr>
<tr>
<td>D3S1358 13</td>
<td>Count</td>
<td>0.073</td>
<td>0.025</td>
<td>0.038</td>
<td>0</td>
<td>0.028</td>
</tr>
<tr>
<td></td>
<td>Frequency</td>
<td>7 to 8 out of 100</td>
<td>2 to 3 out of 100</td>
<td>3 to 4 out of 100</td>
<td>0 out of 100</td>
<td>2 to 3 out of 100</td>
</tr>
<tr>
<td>FGA &lt;18</td>
<td>Count</td>
<td>0.048</td>
<td>0.005</td>
<td>0.005</td>
<td>0.0081</td>
<td>0.028</td>
</tr>
<tr>
<td></td>
<td>Frequency</td>
<td>4 to 5 out of 100</td>
<td>&lt;1 out of 100</td>
<td>&lt;1 out of 100</td>
<td>&lt;1 out of 100</td>
<td>2 to 3 out of 100</td>
</tr>
</tbody>
</table>
when cross-analyzed with STR loci and population databases. Due to the limited overlap of the partial profiles obtained from the isolated needles and the needle associated with the syringe, it was not possible to determine if particular individuals contributed their DNA to more than one sample.

**GC/MS Recovery of Morphine**

Archaeologists frequently recover medicine bottles, opium bowls, and syringes in different archaeological contexts. Although no known published accounts of successful morphine residue recovery from historic artifacts exist, forensic scientists have attempted to extract drugs from a few artifacts. The discovery of opium bowls on a California site prompted archaeologists to verify the presence of opium on their artifacts. Archaeologists delivered the opium bowls to the Los Angeles City police crime laboratory for analysis. The laboratory results were negative for opiates (Greenwood 2002).

Yet another project tested several medicine bottles from a doctor’s refuse deposit at Camp Baird in South Carolina. The bottle residue also tested negative for opiates (Espenshade 2001). Although the tests for opiates were negative on the bowls and medicine bottles, this does not mean drug users did not smoke opium or the medicine did not contain opiates. Opiates, recovered from the poppy plant, are organic and prone to degradation over time. The inability to detect opiates from these samples only indicates a negative test result, not necessarily an absence of the narcotic in the medicine.

Since doctors and addicts almost exclusively injected morphine hypodermically during the last half of the 19th century, Intermountain Forensic Laboratory, Inc., tested the syringe glass found at 18 North G Street for morphine. Initial steps included placing the glass fragments from the hypodermic syringe in a test tube with 1 mm of methanol to wash morphine residue from the artifact. Using controls with each test, Grimsbo concentrated and injected the samples into a GC/MS unit. Morphine was identified neither on this initial test nor on subsequent assays. Realizing morphine is an organic compound that breaks down over time, Grimsbo combined fresh morphine and methanol and centrifuged the mixture in a test tube. Attempting to break down the opiate synthetically, Grimsbo degraded the morphine sample through irregular exposures of heat (up to 70°C), cold, and room temperatures. After several weeks, Grimsbo introduced 1 mm of methanol to the mixture and centrifuged it for an additional five minutes. After the mixture settled, he extracted and placed the liquid sample into smaller centrifuge tubes. The next step involved injecting the sample into the GC/MS. Using the synthetically degraded morphine, Grimsbo designed a program on the GC/MS to recover low amounts and degraded morphine based on selective ion monitoring.

When Grimsbo injected the extracted sample from the glass syringe on the selective ion monitoring program, the results were positive for morphine. While modern morphine is defined by the mass charge of 42 and 124 at just under 200,000; 162 at 500,000; 215 at 400,000; and 285 at more than one million; the degraded sample recovered from the artifact exhibited the mass charge of 42 and 124 at 750; 162 at 600; 215 at 400; and 285 at 700. Although the abundance of the ions recovered in modern morphine is much higher, the defining ions are still present in the 125-year-old morphine residue recovered from the glass syringe, albeit in much smaller quantity. In other words, the GC/MS successfully identified degraded morphine from the sample and proved that the hypodermic syringe recovered from beneath the floorboards was used to inject morphine.

**Discussion**

Since the dwelling house was likely built during the 1860s, it is possible renters before or between the occupations of Mrs. Andrews and the Cooper family used the hypodermic syringe. Since 19th-century physicians viewed the hypodermic injection of morphine as a contraindication for children, Thomas Cooper probably did not purchase the glass hypodermic syringe from a local pharmacy to treat family ailments (Bartholow 1882:60). Additionally, the Coopers carpeted their floor, and archaeologists recovered the loose needles under the charred carpet and floorboards. Furthermore, archaeologists did not recover medical paraphernalia inside the charred remains of the Cooper’s home. It is more probable the needles fell between the
floorboards from a previous occupant who did not carpet the rooms.

It is not possible to ascertain whether Mrs. Andrews had carpeting in her shop. Archaeologists recovered straight pins and beads beneath the dwelling, but these items also occur in domestic deposits. The multiple sets of alleles are difficult to explain. Her marital status, career status, and membership as a Daughter of Temperance do not automatically exclude Mrs. Andrews from having been a drug user. In fact, her death may have been related to an illness requiring regular morphine injections. When the finding of multiple sets of alleles on the syringe needles are considered along with the lifestyle of a married temperance member who supported her family as a dressmaker, the possibility of Mrs. Andrews's participation in morphine injections for medical reasons or recreational use seems unlikely. Instead, the lack of evidence to directly link historically documented occupants with morphine use connects unrecorded participants with medical or recreational morphine injections to 18 North G Street. Although genetic test results fall short of providing archaeologists an unequivocal determination of the syringe users and their motivations for morphine use, the results do point to possible scenarios associated with both recreational and medicinal purposes.

Recreational Use: Prostitute Crib or Flop House?

Recreational drug use was common in Europe and America as well as in Virginia City, where citizens smoked opium in dens, consumed alcohol in saloons, and injected morphine in homes. Historical accounts of morphine use among the upper class abound in the historical literature; however, the low cost and increased sense of euphoria also encouraged regular use among lower income populations (Courtwright 2001:39–40). Both European and American physicians and pharmacists recognized consumption of opiates for recreational use among their clients, especially the working class (Berridge and Edwards 1987:106). An account given in the New York Tribune (1878) stated, “A dangerous method of using morphine to produce pleasurable sensations is believed by physicians in the city to be a growing vice.” The consumption of morphine, either orally or hypodermically, was said to induce a warm glow of loving kindness, a feeling of hope, and a mental calmness (Bartholow 1882: 63–64). Opiate users found the injection of morphine faster, more potent, and less expensive than opium smoking and alcohol consumption. Between 1870 and 1883 smoking opium cost $6 per pound and morphine only cost $1 per ounce (Courtwright 2001:17,71). Only a few grains composed one morphine treatment.

Doctors and patients purchased morphine and syringe kits in Virginia City pharmacies by the early 1870s (Territorial Enterprise 1873b; Clark 1973:868). As seen in other American cities, the easy access to drugs and accompanying paraphernalia gave rise to recreational drug use in the mining West. Alfred Doten described the condition of a morphine addict in his journal, “Evening I helped carry Hunter down from the house where he lived. His arm is very bad. The arm has been badly poisoned by the injection of morphine and creosote into it. Ligatures of elbow joint rotted away, and also the periosteum rotted away for two or three inches each side of the joint-necrosis or decay of the bone had already set in” (Clark 1973:1018–1019). Although Doten fails to mention whether Hunter’s first morphine injection was for pain or pleasure, his opiate dependence is obvious.

The forensic results from the 18 North G Street syringe, along with the historically recognized rampant abuse of opiates during the 19th century, suggest a similar scenario could have taken place at 18 North G Street. The scenario, involving at least four adults, one of whom may have been of African descent, depicts a social gathering where morphine was injected for euphoric effects during the latter 1860s and early 1870s; the multiple sets of alleles found on the syringe are easily explained through sharing with a variety of companions. But who were those people?

Perhaps a male passed around his syringe in a social setting or possibly a female prostitute shared a morphine-filled syringe with her clients. A small home would have easily transformed into a prostitute crib. The urethral irrigator could be connected with prostitution, as it could have been used by an unidentified male or female to alleviate pain caused by venereal disease symptoms.
Whatever their identities, the syringe owners discarded dull, damaged, and/or clogged syringe needles onto the floor where they fell between the cracks. Although discretion is implied, it remains a mystery how the syringe and urethral irrigator came to be deposited beneath the floor. When the glass syringe became inoperable, possibly due to failure of the leather packing, someone might have thrown it beneath a loose floorboard where it broke. Another possibility is the user stored the syringe and urethral irrigator beneath the floor and never retrieved them.

**A Doctor in the House?**

Western communities allowed all types of “doctors” to practice their trade. Miners, living unhealthy lifestyles, attracted many types of physicians, including regular, irregular (homeopathic and eclectic), and herbal. Society viewed doctors who never obtained traditional medical training as “quacks” (Sohn 1997:19). Many 19th-century physicians blamed the informally educated doctors for habitually administering morphine injections and consequently addicting their patients. These uneducated and unethical doctors charged less money and provided a “quick fix” to many members of the underworld.

The hypodermic injection of medicines became widely accepted across America during the 1860s and 1870s. Morphine was the first and most common drug injected subcutaneously. Although the injection of quinine, caffeine, atropine, alcohol, strychnine, and other drugs quickly followed, doctors injected morphine approximately 90% of the time (Bartholow 1882:14–15; Haller 1981:1677). Nineteenth-century physicians had little knowledge of the cause of diseases and turned frequently to the administration of painkillers. Doctors often treated chronic diseases such as arthritis, dysmenorrhea, and neuralgia as well as symptoms of syphilis and gonorrhea with opiates. Early management of venereal diseases involved irrigating the urethra with potassium permanganate or sandalwood oil and prescribing morphine (Goodenough 1904:375).

Virginia City doctors carried a syringe to house calls by the mid-1860s (Clark 1973:946). If indisposed, doctors often sent a trusted friend to homes needing medical services. On one occasion, Dr. Hiller instructed Doten, a Virginia City newspaper editor and occasional medical assistant, to “see a sick person, collect a note for $250, and take medicines and a big syringe in case of emergency” (Clark 1973:946). In chronic cases physicians left morphine and a syringe with the patient to allow self-medication. Patients also purchased their own syringe kit from the local pharmacy or through mail-order catalogs (Territorial Enterprise 1874a).

Given this context, an additional scenario to emerge from the DNA findings on the syringe and associated needles is the occupation of the small dwelling house by a health professional who specialized in the treatment of venereal diseases. Prostitutes and their clients commonly carried sexually transmitted infections. A doctor, located between Virginia City’s red-light district and Chinatown, would have a steady business treating symptoms of syphilis and gonorrhea. Injecting several patients with the same needle explains the presence of multiple sets of alleles on one needle. The nearby hard rubber irrigator, used to flush the urethra, supports a relationship with a doctor who treated venereal disease symptoms. Men or women of African descent, such as Jamaicans and African Americans, along with Caucasians and Hispanics could have been patients. This too might account for the multiple users’ DNA profiles. The placement of the syringe and urethral irrigator beneath the floorboards suggests temporary storage or quick clean up. Disposal of medical supplies beneath a loose board is a quick and attractive alternative to an open refuse pile, especially in a neighborhood full of children.

**Conclusion**

Although the results of the nuclear DNA testing did not determine whether the hypodermic glass syringe represented recreational use or medical treatment, the findings do call attention to the rather unsanitary reuse and/or sharing of needles and the potential for morphine use as a form of recreation between male and female Victorians in the mining west. Forensic tests also revealed the glass hypodermic syringe injected morphine into at least four men and women. In addition, the DNA tests with allele frequency databases, along with neighborhood demographics, suggest at least one person of
African descent may have either participated in recreational drug use or sought medical treatment from a doctor.

The successful recovery of historical genetic material from inanimate objects opens up a new avenue of inquiry for archaeologists and introduces an additional data set to aid in the interpretation of human behavior within past environments. As in criminal cases, by using physical evidence and DNA archaeologists can potentially link people to an archaeological site without historical documentation. In some situations, the profile of the suspect or behavior of an historic person may not be identified by name but by sex and ancestry. As illustrated by the DNA signature of the syringe users, the successful recovery of genetic data opened a realm of considerations for interpreting personal artifacts within an archaeological context. The significance of these findings is not only in the test results but in the demonstration of the technology’s potential for addressing questions that otherwise would have been left unanswered or, perhaps worse, not even asked. In the future, forensic applications in the new specialty of genetic archaeology will inevitably build a body of data that will transform archaeological interpretations of human behavior into more intricate, valid understandings of the past.

Acknowledgments

The author would like to thank Douglas D. Scott for direction and support of this paper and volume. Raymond Grimsbo at Intermountain Forensic Laboratory, Inc., funded and performed the nuclear DNA testing and GC/MS analysis on the medical artifacts. His patience and mentoring in the laboratory is acknowledged and greatly appreciated.

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Survival of Biological Evidence on Artifacts: Applying Forensic Techniques at the Boston Saloon, Virginia City, Nevada

ABSTRACT

The Boston Saloon was an African American-owned business that operated during the 1860s and the 1870s in the mining boomtown of Virginia City, Nevada. Most materials recovered from this establishment are similar to artifacts from other Virginia City saloons due to the widespread availability of mass-produced items. This challenges any attempt at investigating relationships between gender and ethnicity from saloon artifacts. Cooperative efforts between forensic sciences and historical archaeological studies provide a solid foundation for developing unequivocal interpretations of these topics by extracting DNA from common, mass-produced artifacts. Specifically, these efforts resulted in the retrieval of a DNA profile from a clay tobacco pipe stem. Choosing the pipe stem and other likely candidates that could have served as material hosts for ancient DNA (in this case, at least 125 years in age) was a learning process, the results of which may require archaeologists to modify standard recovery methods so as to maximize information retrieval. This process led to other techniques, such as the use of a gas chromatograph-mass spectrometer (GC/MS), to identify residues on artifacts.

Introduction

The Boston Saloon operated from 1864 to 1875 in the mining boomtown of Virginia City, Nevada. William A. G. Brown, an African American from Massachusetts, owned this establishment and catered to an African American clientele. Brown arrived in Virginia City by 1863, at which time he worked the street as a shoe polisher (Kelly 1863:2). By 1864 he went into business for himself and opened a saloon on B Street, an area upslope from and well outside of the center of town (Collins 1865:3). Sometime between 1864 and 1866, Brown moved his business known as the Boston Saloon from that location to the southwest corner of D and Union streets (Territorial Enterprise 1866; James 1998:154). The new location sat in the heart of Virginia City's commercial corridor and entertainment district (Figure 1).

Brown operated the Boston Saloon at the bustling corner of D and Union streets until 1875, at which time the establishment disappeared from historical records. With the exceptions of scholarly work such as that by Elmer Rusco (1975), Michael Coray (1992), and Ronald James (1998), this and other stories of African Americans in northern Nevada and the mining West faded from the region's popular history and memory. Then, in summer 2000, a public archaeology project at the Boston Saloon site, conducted as part of the author's dissertation research under the direction of Donald L. Hardesty, revived a segment of that memory using an array of public outreach approaches (Figure 2).

The first archaeological examination of an African American saloon in the West, the Boston Saloon project unearthed the story of a physical place where people, specifically people of African ancestry, shared leisure time within the confines of a white-dominated setting. Historical sources describe the Boston Saloon as...
the “the popular resort of many of the colored population” (*Territorial Enterprise* 1866). Additionally, an African American writer for the *Pacific Appeal* (1875) described his desire for “a place of recreation of our own” in Virginia City after the Boston Saloon closed. Wording in the sources noted above suggests that the Boston Saloon catered to people of African ancestry.

Nineteenth-century writers claim that there were about 100 saloons in Virginia City and its neighboring community of Gold Hill during the region’s mining heyday (Lord 1883:377). Shrewd business people filled niches in such a saturated industry, creating a range of drinking establishments: “saloons of all descriptions, from the spacious rooms furnished with walnut counters, massive mirrors, and glittering rows of decanters to the cheap pine bar with its few black bottles, were to be found on every street land and corner” (Lord 1883:93). Virginia City had ample clientele to support the classier establishments as well as the more sordid places (Hardesty and James 1995). Many of these upscale drinking establishments also offered “secluded” rooms for the town elites so that these “gentlemen … might relax with their own kind … free from the noise and confusion of the streets … and the unwashed masses” (West 1979:40–41).

The descriptions of the Boston Saloon are reminiscent of the fact that drinking houses were segregated, not only by socioeconomic but also according to ancestral backgrounds. Furthermore, some drinking places filled other niches by providing various forms of female companionship, from dancing partners to more intimate forms of leisure (West 1979:48–49). This underscores the relevance of integrating analyses of economic position, such as class, with other issues pertinent to understanding the diversity among western saloons, including gender and ethnicity. Terms such as *ethnic* or *ethnicity* represent an over-used concept in anthropological vocabulary because it lacks biological and scientific validity. Some scholars are calling for its demise as an analytical concept (Banks 1996:10,188). Even so, it is a prevalent concept among historical archaeologists due to its ability to convey relation-
ships associated with ascribed and self-ascribed ancestral identity. While relevant to research at the Boston Saloon, all of the above represent core research issues in historical archaeology as consistently attested to by the discipline’s literature (Little and Shackel 1989; Rothschild 1990; McGuire and Paynter 1991; Ferguson 1992; Mrzowksi 1993; Wall 1994; Hodder et al. 1995; De Cunzo and Herman 1996; Shackel 1996; Jones 1997; Burke 1999; Mullins 1999; Tarlow 1999; Wurst and Fitts 1999; Jamieson 2000; Brown 2001; Praetzellis and Praetzellis 2001; Davidson 2002).

Testing Artifacts for DNA

Elegant glassware, sophisticated interior fixtures, and high-quality meat cuts from the Boston Saloon aid interpretations of this establishment’s relatively upscale setting in the context of other contemporary Virginia City saloons, but unequivocal resolution of the discipline’s other major research issues, namely ethnicity and gender, remained elusive (Dixon 2002). Mass-produced items, including various beverage bottles, tobacco pipes, glassware, and ceramic wares, dominate this saloon assemblage. Without oral histories or the ability to interact with members of a descendant community, those materials do not easily lend themselves to unequivocal ethnic or gender-based interpretations.

Yet if remnant DNA could be lifted from certain objects, such interpretations may be substantiated because DNA molecules carry hereditary information and may reside on certain artifacts. This means that DNA tests can help archaeologists determine who used specific items or at least determine the sex and perhaps the ancestry of the users. With this in mind, a selection process commenced to identify artifacts that appeared to be good candidates for maintaining DNA profiles that were at least 125 years old.

A variety of body fluids, such as blood, sweat, semen, saliva, as well as buccal or cheek cells contain high concentrations of DNA. Artifacts that came into contact with those fluids or cells were assessed as prime candidates. Artifacts such as a tobacco pipe stem fragment marred with teeth clench marks appeared to be a good candidate as clench marks indicate that this object made contact with the inside of someone’s mouth (Figure 3). The porous nature of the pipe stem’s clay composition provided tiny catchments to harbor DNA molecules through time. Additionally, the pipe stem’s borehole inadvertently protected those molecules from ultraviolet (UV) rays. UV light can cross-link DNA molecules, leading to their degradation by affecting their molecular structure (McNally et al. 1989:1062).

Fortunately, UV rays did not affect the remnant DNA on the inside of the pipe stem’s borehole in the area of the teeth clench marks. Testing on this item recovered one female DNA profile from the area near the borehole and the tooth marks, providing evidence that a woman was associated with at least one tobacco pipe from the Boston Saloon. While one woman’s DNA does not overturn powerful stereotypes, this conclusion provides an explicit incentive for rethinking the male-dominated imagery of the western saloon (West 1979:145). Forensic laboratory technicians then conducted calculations for people of various ancestral genetic backgrounds using allele frequency and distribution data as a means of determining the population origin of this woman.

Bruce Budowle and colleagues (1999, 2001) found that allele frequencies at specific physical locations or loci on a gene’s chromosome are similar within the same major population group. That study’s population groups include terms such as African American, Asian, Bahamian, Caucasian, Hispanic, and Native American. It is essential to point out that this allele frequency (Budowle et al. 1999, 2001) and rare allele variant research merely provides information about population origin. It does not, by any means, allow conclusive determinations of “race,” a concept that lacks biological and scientific validity (American Anthropological Asso-
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Survival of Biological Evidence on Artifacts

While this type of research emphasizes genetic variation in place of such social constructions, the databases still maintain predictive potential to approximate underlying biological variation.

Although there are discussions for making conclusions about certain population origins using rare allele variants (Budowle et al. 1999, 2001), in this case the tobacco pipe profile from the Boston Saloon did not contain the type of allele variant associated with any one population group. While the profile lacked the variant purportedly conducive to identifying the population origin of the woman who may have used the pipe, the findings still inspired and demanded an inductive new research direction aimed at the topics of gender, African American ancestry, and leisure settings in the American West. This multidisciplinary interplay of biological remains, historical data, and archaeological context encouraged a scientifically informed revisit to traditional, documentary research.

This inspection of primary and secondary records indicated that racially segregated leisure prevailed in the 19th-century West (Territorial Enterprise 1866; Pacific Appeal 1875; Phillips 1970; Captain 1995; Lang 1998; Porter 1998). For example, some drinking establishments and gambling halls exhibited informal segregation within the same building, with white cowboys served at one end of the bar and black cowboys at the other (Porter 1998:124). Additionally, the U.S. Army barred black men from dancing with white women. On occasion black soldiers attended dances given by white soldiers, but there was an underlying understanding that the black soldiers would not seek dance partners among the white women (Phillips 1970:140).

If interracial dancing inspired the ideology for more strict lines of segregation, so, too, did more intimate leisure activity. Brothels were highly segregated because the majority of prostitutes were white. There are reports of “soiled doves of color” who worked in cattle towns in the West to provide an alternative for black cowboys who were barred from brothels staffed with white prostitutes (Phillips 1970:140). The above research suggests that, for the most part, black men and white women did not mix in leisure contexts in the West. Given this analogy, it is highly probable that most women in 19th-century saloons dedicated to African American clientele were of African ancestry, and it is quite likely that the woman who held that pipe in her mouth at the Boston Saloon was also of African descent.

The unexpected discovery of a woman’s DNA on this object instantly unraveled prevalent, white, male-oriented stereotypes of western saloons and informed more detail on gender-based associations with tobacco use (West 1979:145). In regard to women’s association with tobacco use during the 19th century, other researchers suggest that smoking was primarily limited to men. While women did participate in this activity, they risked the stigma of being considered immoral if they did so (Cook 1989; Hardesty 1994:137; Mrozowski et al. 1996:67–68).

In the event that the allelic profile on the pipe stem was actually modern or contaminant DNA, it was compared against sample DNA of the archaeologist who handled the pipe stem and the forensic laboratory personnel to determine whether those who had the most recent, close contact with the object did or did not contaminate it. Their profiles differed from that recovered from the pipe stem, indicating that the sample was neither contaminated by the archaeologists in the field nor laboratory technicians. The preliminary tests indicated a woman’s DNA. These test results influenced the above gender-based discussions and expanded personal paradigms. A database of historic DNA samples has yet to be developed to build on these experiments and to reconfirm their findings. In the meantime, other artifacts from the Boston Saloon were examined for supplementary tests.

A set of porcelain dentures recovered from the Boston Saloon excavation showed potential (Figure 4). Due to the porosity of the porcelain and the contact the dentures had with the inside of someone’s mouth, they seemed a promising

FIGURE 4. Porcelain denture fragments recovered from the Boston Saloon site. (Photo by Julie Schablitsky.)
candidate for DNA recovery. Even though laboratory technicians swabbed the dentures thoroughly, the sample was negative for human DNA, possibly due to environmental factors such as UV degradation.

In fact, the UV degradation may have been the result of archaeological excavation methods. It is necessary to share the learning process related to the possible loss of DNA in order to prevent the loss of data from future material candidates. Most artifacts from the Boston Saloon were temporarily exposed to UV rays, both during their original deposition in an alleyway dump behind the saloon and when archaeologists re-exposed them during excavation. Environmental factors, such as UV light and temperature and moisture fluctuations degrade DNA (Rudin and Inman 2001:13). Unaware of their potential for DNA analysis at the time of excavation, the archaeology crew inadvertently exposed the dentures to UV radiation.

First, the crew pedestalled objects such as the dentures for in-situ recording and photography, which unnecessarily exposed those items to damaging UV rays (Figures 5, 6). When the crew finally removed the objects, they did so in a public archaeology context, sharing these artifacts with visitors and thereby subjecting them to further contamination. In contrast, artifacts such as the aforementioned tobacco pipe stem seemed rather uninteresting after unearthing and were not shared with the public. Although the laboratory was unable to recover historic period DNA, the lesson here is to protect objects that are candidates for DNA testing from unnecessary UV exposure and other sources of contamination by (a) expeditiously recording their provenience; (b) using latex gloves to prevent contamination while removing the items from harmful environmental conditions such as inclement weather and sunlight; (c) placing them in paper envelopes; (d) and storing the artifacts in a controlled environment such as a freezer (Schablitsky 2003). To increase the likelihood of successful DNA recovery, archaeologists must attempt to halt any degradation already in process by limiting...
any further deterioration of a sample (Rudin and Inman 2001:14).

The Boston Saloon excavations also yielded a brass trombone mouthpiece (Figure 7). From the standpoint of archaeological interpretation, this object had the ability to revise the stereotypical idea of piano accompaniment in the western saloon. Additionally, a newspaper account refers to a “black band” in Virginia City that played for certain African American social events (Territorial Enterprise 1877). Was it possible to link this mouthpiece with a musician of African ancestry, such as a member of the band noted in historical records?

Potentially, DNA tests could provide evidence about the trombone player’s ancestral background to assess the possibility for making unequivocal determinations about the presence of African American performers in the Boston Saloon (Budowle et al. 1999, 2001). The mouthpiece was a prime candidate for DNA recovery because it came into contact with someone’s mouth and served as a receptacle for saliva during musical practice. The mouthpiece’s brass composition includes zinc and copper. Copper is significant since it acts as a preservation agent for organic material. The association of cupreous materials with organic archaeological deposits demonstrates a unique preservation situation. Copper emits salts that prevent bacteria from breaking down organic materials in buried contexts (Dixon 1994:188; Martin 1999:143).

Despite its promising qualities, the trombone mouthpiece did not yield any DNA. Forensic technicians swabbed around the interior of the mouthpiece but failed to recover any remnant DNA. The lack of recovery of DNA from this object is informative. First, it reveals that the mouthpiece was not contaminated with modern DNA or other exogenous DNA. Second, it provides a control sample for the potential of exogenous DNA on artifacts recovered by archaeologists at the Boston Saloon. No control samples were taken from areas of the tobacco pipe stem mentioned above, other than the
locale with teeth clench marks. By providing negative DNA results, the trombone mouthpiece stands as a control of sorts because it shows that investigator DNA did not pervade the entire collection, which strengthens the case for the DNA on the tobacco pipe stem to represent a noncontaminated sample.

Exfoliation of the metal on the mouthpiece may have been a contributing factor in the loss of DNA residue from the trombone mouthpiece, as the original surface containing extant molecules had long since sloughed off. While this represents a failed attempt at recovering DNA from a cupreous object, Julie Schablitsky’s (2002:6) discoveries with the 125-year-old, rolled copper syringe needles are testament to this metal’s beneficial preservation potential for DNA extraction from inanimate objects.

**Testing Artifacts Using GC/MS**

Forensic laboratory technicians initially hoped to extract DNA from a stoneware crock lid sherd marked with a brownish-red stain (Figure 8). This looked like a dried bloodstain, and it became a prime candidate for DNA testing. Prior to conducting a DNA test, the forensic laboratory needed to determine if the substance was blood. The determination of blood in samples for forensic cases involves a Kastle-Meyer color test, which requires the mixing of the chemical phenolphthalein, hydrogen peroxide, and the sample. If the substance is indeed blood, the blood’s hemoglobin then emits a deep pink color (Saferstein 2001:327). As a control while conducting the Kastle-Meyer test, the forensic laboratory staff obtained a sample of known human blood, placed it in the solution described above, and examined the pink color. Next, the forensic scientist at the laboratory obtained a sample of the stain on the crock lid and used the same procedures. The deep pink color did not appear, indicating the absence of hemoglobin from the stain and suggesting that it was not blood.

While the Kastle-Meyer color test cast doubt on the likelihood of DNA recovery, it did not exhaust the stain’s data potential. What was the substance? Was it a lead-based paint stain? To address this question, the forensic laboratory used rhodizonic acid to determine the presence of lead in the stain. This test is common in criminal cases where it is crucial to determine lead residues associated with munitions (Nowicki 1982). If a substance such as the stain on the crock lid contained lead, a sample of that substance in a solution with acetic acid would assume a pink or purple hue in reaction to rhodizonic acid. The forensic scientist obtained a second sample from the stain and exposed it to rhodizonic acid. The pink or purple colors did not appear in the solution, indicating that the stain tested negative for lead.

When the sample tested negative for lead, another question arose: was the stain a remnant food product associated with the crock lid’s use for food preparation or storage? The archaeological record helped refine this question as a result of a number of pepper sauce bottles, one of which was a rare Tabasco bottle (Figure 9) recovered from the Boston Saloon. This opportunity led to gas chromatograph-mass spectrometer (GC/MS) testing for capsaicin in the stain (Figure 10). Capsaicin is extracted from the cayenne pepper, *Capsicum frutescens*, and is noted as the primary “hot” ingredient in McIlhenny’s Tabasco sauce; Worcestershire sauce similarly includes “chile peppers” among its ingredients, and samples of these wares were recovered from the Boston Saloon as well.

Capsaicin is an ingredient of cayenne-pepper-based chemical protection sprays that require analysis in many criminal and forensic cases. As
a result, there is mass spectroscopy-based literature that provides a methodology for extracting and identifying this ingredient using GC/MS techniques (Nowicki 1982). The potential for extracting pepper sauce from the stain on the crock lid subsequently benefited from this literature and the associated research on capsaicin.

During GC/MS examinations, the stain tested positive for capsaicin, suggesting that it did indeed represent a red pepper-based substance and likely represented a pepper sauce such as Tabasco. The GC/MS tests did not recognize capsaicin in other pepper-based products found at the Boston Saloon, such as Worcestershire sauce, indicating that the stain likely represented a product more like Tabasco sauce rather than Worcestershire sauce. The GC/MS also indicated the presence of lipids, such as those from animal fat, in the stain. The test results suggested the use of a red pepper sauce on at least one meat-based menu item associated with the Boston Saloon. The Boston Saloon’s faunal record indicates meat-based menu items included an abundance of high-quality cuts of lamb and beef (Dixon 2002:146–172). The stain provides a rare archaeological remnant of this saloon’s cuisine. This is a refreshing bit of information, given the fact that newspaper advertisements for Virginia City saloons vaguely referred to their meals as “Lunches” or “Hot Lunches” (Territorial Enterprise 1867a, 1867b, 1867c).

Conclusions

While the stain on the crock lid veered research away from DNA analyses, forensic techniques nonetheless yielded other information that helped associate this object with a detailed recovery of the leftovers from a meal served at the saloon. More importantly, techniques associated with forensic science—especially DNA recovery—can help archaeologists make unequivocal interpretations about the people who handled and used the artifacts they excavate. In other words, these techniques facilitate determinations of sex and ancestry from mass-produced artifacts that may not, on the surface, allow such determinations without severe speculation. As a result, DNA analyses can help archaeologists say whether relatively commonplace objects, such as tobacco pipe stems, musical instruments, syringe needles, or other personal objects were used by someone of a certain sex or population origin. This potential will allow archaeologists to examine issues of gender and ethnicity using objects that do not easily lend themselves to such affiliations.
If archaeologists can validly determine these affiliations, then they can examine whether certain everyday objects can be associated with a particular group of people using DNA profiles recovered from those objects. Then it will be possible to address those ubiquitous research issues associated with gender and ancestral background. If these major historical archaeological topics can be addressed in balance, then it should be possible to base humanistic interpretations on a solid, scientific foundation using forensic techniques. This can be expanded even further if one considers the potential for matching sex and population origin with the abundant artifact categories in every historic artifact catalog. For example, eventually it may be possible to make conclusions such as tobacco pipe types $x$ and $y$ tend to have been used by women, while tobacco pipe types $a$ and $b$ tend to have been used by men.

Forensic sciences offer historical archaeologists the tools to help give the anthropologically necessary but rather equivocal interpretive frameworks a sturdy foundation. This field can also give historical archaeology the tools to provide a valuable, meaningful contribution to its estranged, unimpressed parents—anthropology and history. Such a contribution demonstrates historical archaeology’s ability to bridge science and humanism by telling anthropologists and historians something that they did not know about the past and something that they may not have even thought about at all.

Acknowledgments

A grant from the University of Nevada-Reno Graduate Student Association provided funding for the DNA and GC/MS testing reported in this paper. Raymond Grimsbo and staff at Intermountain Forensic Laboratories ran the DNA and GCMS tests to fit a tight budget. Richard Paul Benjamin offered comments on an early draft of this article. Mark Leney of the U.S. Army Central Identification Laboratory, Hawaii, provided valuable suggestions on an early draft. Thanks also to Donald L. Hardesty of the University of Nevada-Reno and to Ronald M. James, Nevada state historic preservation officer, for support and advice related to this work. Special thanks go to Julie M. Schablitsky for ideas and assistance throughout the duration of forensic testing, for her inspiration to do this paper, and for her editorial advice. Thanks also to the anonymous reviewers. The field and laboratory work on this project results from the cooperation of the following institutions: the Comstock Archaeology Center, the Comstock Historic District Commission, the Nevada State Historic Preservation Office, the University of Nevada-Reno Department of Anthropology, Am-Arcs of Nevada, the Reno-Sparks NAACP, the National Endowment for the Humanities, Storey County, and the Bucket of Blood Saloon.

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Sampling Skeletal Remains for Ancient DNA (aDNA): A Measure of Success

ABSTRACT

More than 2,000 samples of human osseous and dental materials drawn from forensic archaeological casework of the Joint POW/MIA Accounting Command Central Identification Laboratory (CIL) were submitted for mitochondrial DNA testing. Most cases represent unidentified remains of U.S. service personnel from World War II, the Korean War, and the Vietnam War. Ancient DNA sampling technique is discussed in the context of an overall strategy of minimizing the risk of contamination with exogenous DNA. Results achieved through implementation of this strategy are reviewed with the intent of providing historical archaeologists with data to assist them in deciding if human remains should be samples for DNA analyses and, if so, how to maximize the chances of an interpretable test outcome. Sample mass proved an important determinant of probability of successful DNA testing. Skeletal element sampled was also a determinant of success rate, independent of sample mass. Femora, tibiae, mandibles, and first metatarsals were excellent sample sources. Cranial samples had low rates of DNA recovery. Climate of deposition and recovery had a minor effect on success rate with temperate recoveries outperforming tropical recoveries in DNA testing success rates. Contrary to initial expectations, older samples performed better than younger samples. This inverse age effect is attributed to conflict-specific taphonomic processes. The lack of any detectable effect over the past 60 years suggests that as long as bones are well preserved and optimal elements well represented, aDNA testing will be relatively unproblematic over time spans of hundreds of years, certainly encompassing the entire time span considered by historical archaeologists.

Introduction

This study provides historical archaeologists with a framework for making choices about ancient DNA (aDNA) analyses on human remains. Sampling choices and procedures are reviewed in the light of the experience obtained from the testing of thousands of samples in order to help historical archaeologists decide if aDNA sampling is likely to be effective for a specific project. In addition, when a decision is made to proceed with aDNA sampling, guidance is offered on what to sample, how much to sample, and how to sample it.

Bone and teeth from skeletonized remains comprising the forensic archaeological casework at the Joint POW/MIA Accounting Command Central Identification Laboratory, Hawaii (CIL), formerly known as the U.S. Army Central Identification Laboratory, Hawaii, have been widely investigated using specialized aDNA testing. The results of thousands of such tests can provide some guidance to archaeologists seeking to test skeletal and dental material using aDNA.

CIL uses mitochondrial aDNA testing primarily to support individual identification and to resolve commingled skeletal remains. Mitochondrial DNA (mtDNA) is targeted as it is more reliably recoverable in archaeological contexts than the alternative, nuclear DNA. In addition, while mitochondrial profiles are less individual than nuclear DNA profiles, their inheritance is only matrilineal (mother to child) without mixing with paternal DNA. The matrilineal-only inheritance means that the mitochondrial profile passes essentially unchanged from generation to generation, which allows quite distant blood relatives to be used as a source of reference material for comparison to the profile developed from the historical remains. To a limited extent, aDNA test results at CIL are also used to provide supporting evidence of the ancestry of the individual, which can, with some caveats, be compared to the race and/or ethnicity data as recorded in military service records. CIL analysts are routinely tasked with providing suitable samples of skeletal material for aDNA testing. A number of issues should be considered, which can be condensed into three basic questions: (1) What special procedures are warranted for an aDNA sample and the source material? (2) What material makes a suitable sample? (3) How much of it is needed?

Sampling Archaeological Materials for aDNA: General Issues

The special procedures required revolve around the need to obtain and document the sample, preserving sufficient target aDNA
without introducing contaminant or exogenous DNA. Ancient DNA testing uses the polymerase chain reaction (PCR) to amplify specific lengths of tiny amounts of original DNA to volumes where sequencing can be achieved. DNA exogenous to the sample can also be amplified, sometimes preferentially, to yield a problematic sequencing result. Typically, selection of amplification primers conserved within but not between species means that the DNA amplification target is species-specific. Contaminating microbial and fungal DNA will not amplify when human-specific primers are used on a sample obtained from human bone. On the other hand, contaminating human DNA is potentially a huge problem. How does one eliminate the possibility that DNA sequence data obtained from the amplification product is derived from the contaminant rather than the target DNA? The same problem might occur in other species studied, if modern comparative exemplars were co-located with the archaeological material believed to be of that species. In this scenario, a claim that nonhuman, species-specific DNA was obtained from archaeological material is undermined if the archaeologists handled the material to be tested together with comparative faunal material.

The most problematic contamination concerns archaeological human remains, given the ubiquity of humans at virtually every stage between excavation and DNA analysis. The problem is far from trivial; the large quantities of DNA in fresh biological material means that a few skin cells, traces of sweat, hair, or even the epithelial cells carried in the microdroplets on human breath can contain quantities of DNA equal to or exceeding those recoverable from the aDNA sample. Luckily this sort of contaminant DNA is generally not very stable. While the aDNA residue in the bone is protected by the hard tissue that surrounds it, contaminant DNA is generally superficial and short-lived, given its exposure to oxygen, moisture, and perhaps natural ultraviolet (UV) radiation. All environments containing live humans are subject to a continual and inevitable barrage of contaminating DNA. While it is possible to put barriers around the material to be sampled, something that has to be reconciled with the need to perform traditional cleaning, stabilizing, and curatorial practices in addition to conventional study. Secondly, where there are inevitable exposures of the sample material, sampling area, or sampling equipment to a potential contamination, procedures can be used to destroy or render contaminant DNA nonamplifiable. Thirdly, the sample itself can be decontaminated. Any procedure on the sample needs to weigh the risks of adding fresh contamination or reducing either the sample volume or the amount of recoverable endogenous DNA within it.

Once the sample is safely consigned to the DNA laboratory, the responsibility of the archaeologist for the physical integrity of the sample is over. Given the short half-life of most contaminant DNA, the closer a superficial contamination event is to the PCR amplification stage, the more problematic it is. Archaeologists visiting facilities processing aDNA will note that the steps taken to mitigate contamination risk are proportionately greater in the final stages prior to amplification. Such methods include continual irradiation of work areas during periods when work is not taking place, strict separation of preamplification, and DNA-rich postamplification laboratory areas. These protocols generally preclude staff who have worked in postamplification spaces from re-entering preamplification spaces on the same day. Separate air-circulation systems, regular bleach-downs of workspaces and even entire lab suites, and strict adherence to the use of clean headgear, gloves, facemasks, and laboratory coats are critical. Experience with CIL casework has shown that it is not necessary to extend the full range of such protective measures back into the archaeology laboratory or to the excavation site. As the risk that contamination will be problematic declines the further it is displaced in time from the amplification stage, select components of the protective measures can be applied in order to achieve a reasonable balance between mitigating contamination risk and permitting other important archaeological activities to proceed smoothly.

Finally, there are some postamplification procedures that can further ensure the integrity of the aDNA test. A tedious and expensive technical fix to the contamination problem is the cloning of the amplification product from
contaminated material. In this procedure the mixture of target and contaminant DNA is cloned into vector organisms. Each of these takes up a single stretch of amplification product, either the aDNA target sequence, or a contaminant sequence. Single-vector organisms are cultured, carrying the amplified DNA fragment along in each generation. Each culture is subjected to further DNA analysis. For an example, see the work by M. Krings and colleagues (1997) to separate the sequence of the original Neandertal remains from generations of curator contamination. The result is no longer an unresolved mixture of DNA types but a population of distinct types derived from the components of the original mixture. Some interpretation is required: Which, if any, of the two or more types of DNA present is the original aDNA target endogenous to the sample? Which is exogenous to the sample? At this point it is worth discussing a more straightforward remedy to interpreting contamination as it also relates to the interpretation of cloned mixture components.

One of the final tests of authenticity of aDNA results, mixtures aside, is the credibility of the result obtained. Does the result make sense in the context of all the other data available? Clearly if the same sequence was obtained more than once independently, preferably in different laboratories, this reinforces the credibility of the result. If archaeologically associated materials, say teeth and long bones from the same burial, yield concordant sequences distinct from collocated materials, this would be a stronger result than an isolated aDNA sequence. The result is more credible still if the laboratory personnel were unaware of the prior archaeological associations. Laboratory personnel might legitimately be concerned if multiple left femur samples submitted all yielded the same sequence. A single sequence detected consistently in multiple individuals looks like a ubiquitous contaminant. If, however, the archaeologist already suspects that the individuals include a mother and her offspring, multiple concordant mtDNA sequences are exactly the results expected. Sense criteria are much discussed by aDNA practitioners (Cooper and Poinar 2000; Hofreiter et al. 2004) and represent efforts to build credibility for a new discipline. On the other hand, the danger of sense criteria is the risk of rejecting unexpected results. That is, if results do not fit preconceived notions, there is a hazard that sense criteria will cause good data to be rejected as some unexplainable contamination.

Archaeologists, DNA laboratory staff, and all individuals who are in contact with sample material should submit their own DNA to resolve or exclude contamination issues. The resulting database provides a tool that usually allows the rapid exclusion of all these potential contaminators. Conversely, if one of the archaeologists has DNA that is consistent with the material obtained from the sample, potentially, there is a problem. A consistent mtDNA sequence does not prove a contamination. A relatively common mtDNA type shared between scientist and sample is less of a smoking gun than a shared rare sequence. Even rare sequences do not positively identify individuals, but they do look suspicious. By and large, the database of scientists is going to offer clear exclusions, and there will be few problems as long as the pool of potential contaminators is kept relatively small. Where there is a potential match, this can usually be addressed by further DNA sequencing of the sample and the “suspect.” Resampling of the archaeological material, by someone other than the “suspect,” can also clarify such situations. If contamination is rare and random, and unless the “suspect” grossly contaminated the source material, a replication of the same sequence data in the second analysis most likely represents the endogenous DNA from the sample. Where practical, a good DNA laboratory will already be splitting the sample and conducting duplicate analyses in order to provide an analogous control over sporadic contamination within the DNA laboratory itself.

There are circumstances where multiple DNA types might be expected from a single sample and do not indicate contamination, for example, shared drug paraphernalia or other artifacts retaining trace DNA from multiple users (Schabitsky, this volume). Nevertheless, this situation is going to be unusual for archaeologists where bone, tooth, and tissue samples will predominate. Most contaminations are therefore likely to be flagged by the detection of more than one type of DNA in a sample. While two DNA types from a single unmixed sample source indicate that at
least one of them is not original, the opposite is not always true. That is, given very little or no amplifiable target DNA in the sample together with contaminating, exogenous DNA, potentially only the contaminant DNA could be amplified. Such a single nontarget sequence obtained that has every other appearance of endogenous DNA is termed a false positive. A false positive result could also arise if the contaminant DNA type was present in quantities sufficient to swamp the endogenous target DNA to the extent that no mixture was detectable in the amplification product. The risk of false positive results is elevated by the submission of test material that has such low levels of original DNA that even very minor contamination could swamp a mixture signal.

How can the archaeologist mitigate this risk? The solution is both simple and complex. If the archaeologist simply refrains from submitting materials for analysis that are grossly contaminated or that contain negligible quantities of recoverable DNA, then by staying squarely in the middle ground of what the technology can accomplish, results are guaranteed to be reliable, interpretable, and backed by a solid empirical pedigree. The complexity arises from the choices that archaeologists must make. Sometimes the samples that promise to answer the most interesting research questions are going to be suboptimal for aDNA analysis. Where does suboptimal material shade into inappropriately, or even irresponsibly, poor samples? This is a determination that archaeologists must make. Sometimes the samples that promise to answer the most interesting research questions are going to be suboptimal for aDNA analysis.

Beyond the special risk of contamination with exogenous DNA, there is one additional source of error in aDNA results. The DNA itself can be modified from its living state by taphonomic processes and is also subject to modification during amplification, as PCR itself does not have perfect fidelity. If abundant aDNA is present, the chances are good that the unchanged aDNA strands at each point will swamp random changes to individual aDNA strands in the sequence. For amplifications with little amplifiable aDNA at the outset, stochastic effects at the beginning of or early in the amplification phase can introduce errors into the sequence data. Mitigation of this risk is also best achieved by staying away from marginal quality samples or at least recognizing material that constitutes a low quality sample and interpreting any results obtained from it with adequate caution.

In forensic science this process of validation is a critical community standard, providing a ready framework within which technical results can be assessed discipline-wide. The samples discussed below go some way towards providing such a framework for the aDNA testing of historic skeletal samples. In addition, it is hoped that this casework experience will help historical archaeologists plan and execute aDNA testing of their material in a timely, scientifically informed, and cost-effective manner that minimizes destructive testing of human remains.

In forensic archaeology, where hypotheses tested and facts ascertained could be probative in criminal proceedings, certainty and interpretability are paramount. Even here, value judgments are required. Tests with an otherwise solid scientific basis can still introduce doubt and confusion in the courtroom, rather than clarity and certainty. Inappropriate forensic DNA testing could undermine an otherwise coherent body of evidence if the sample quality was too
low to justify application of the technique used. In a worst-case scenario, false positive evidence, if accepted in criminal cases, could easily result in wrongful conviction. Conversely, declining to attempt difficult DNA samples could mean that guilty individuals escape justice.

If, on the other hand, the goal of forensic archaeology is the identification of unknown human remains for humanitarian purposes in postconflict situations (as at CIL or in the former Yugoslavia or Iraq), the balance is somewhat different. In such circumstances, good science is just good science and, even if complex and potentially confusing, it can be explained at lengths to the end consumers of the technology in a nonadversarial setting. While it is accepted that sometimes the guilty go free, hoping that they will be convicted and punished for some other offense, the unidentified dead will remain unidentified indefinitely. There is a greater responsibility in such cases to do whatever can be done to resolve identifications, even if this means pushing the limits of technology in a manner that might cast reasonable doubt in the criminal courtroom. Thankfully, most archaeologists will not face such moral calculus, but the need to find the right balance between knowledge and certainty in the application of aDNA technology is common to any study. Archaeologists are well placed to know how much error, if any, they can tolerate in their results. As yet, they lack resources to distinguish the boundaries of acceptable risk and useful results.

**Sampling for aDNA:**

**Practical Solutions at CIL**

Lacking any systematic precedent for the sampling of large numbers of bones for aDNA analyses, over the past decade CIL has developed procedures designed to facilitate aDNA sampling. In consultation with other facilities engaged in forensic and archaeological aDNA work, these procedures are intended to permit proper documentation of the sampling and maximize the chance of a successful outcome, obtaining an adequate (but not excessive) sample, while minimizing the risk of fresh contamination.

When osseous or odontological material is obtained by CIL from the field, efforts are made to preserve the teeth and bone as soon as they are recovered. Typically the bone will be minimally handled and will be removed to whatever secure storage is available as soon as possible. Sometimes handling of material without gloves does occur in the field and, while this is by no means desirable, experience shows that it is not fatal to aDNA analyses of skeletal material. On the other hand, aDNA analyses of trace DNA on artifact surfaces are likely to be completely undermined by casual, ungloved handling in the field. As aDNA is internal to the bone, the surface can be decontaminated. In contrast, aDNA targets on surfaces cannot be decontaminated without destroying the target DNA. The safest procedure is to wear gloves when handling potential aDNA samples sources, osseous or otherwise. Depending on the circumstance of recovery, initial cleaning of the recovered material may take place in the field. Where washing is unavoidable, gloves are used. As bone is porous, washing can transport surface contamination deeper into the bone. Once there, it may be protected from general environmental insult and from specific decontamination procedures that primarily address surface contamination (UV irradiation, bleach swabbing, and surface sanding). It is strongly recommended that bones and teeth be air dried as thoroughly as possible in the field, and that initial cleaning be limited to dry brushing. Where an investigator is committed to aDNA testing in advance, consideration should be given to securing the DNA test sample prior to other cleaning, stabilization, and analytical procedures in the laboratory.

CIL has found that exposure of bones to natural UV light is not a major problem with aDNA analysis. UV is known to cause the rapid dimerization of bases in the DNA molecule (Lindahl 1996) rendering it nonamplifiable. UV radiation cannot penetrate beyond the surface of bones or teeth, so DNA sequestered within the bone is shielded from UV damage. Although CIL has not attempted DNA analyses of trace residue such as blood and has limited experience with the submission of hair, finger nails, and fatty tissue residue for aDNA analysis, a basic understanding of the physics of radiation dosing suggests that aDNA in such samples will be vulnerable to natural UV radiation. Standard archaeological practice in other circumstances where it is critical to avoid new incident
radiation, such as electron spin resonance dating, is to wrap materials in aluminum foil as soon as they are uncovered. It stands to reason that this practice will also minimize UV damage to vulnerable aDNA samples.

CIL practice is to store and transport bone and teeth in previously unused, sealed plastic bags with sufficient desiccant packets to absorb residual moisture. If desiccant is not used, fungal and bacterial activity can be marked. While fungal and bacterial DNA are not amplifiable contaminants, large quantities of nontarget DNA present are co-extracted with the target DNA and may inhibit successful amplification of that target. Microbial activity inevitably degrades the physical integrity of the bone and consumes organic residue, including DNA. No special procedures are used to decontaminate the plastic bags or desiccant. Where materials are recovered in unusual depositional environments such as within pockets of fuel oil or in saline environments, CIL archaeologists are encouraged to keep biological material in its matrix for transport to the laboratory. The rationale for this recommendation is that whatever mechanism is acting to preserve organic residue is likely to be approximately at equilibrium in the matrix from which the material was recovered. Removing atypically preserved material from its matrix may lead to a rapid destabilization of the organic material as the equilibrium is upset, with consequent loss of DNA. If the removal of the matrix can be as close as possible in time to the submission of materials for aDNA analysis, the impact of such destabilization can be minimized. This rationale will be familiar to archaeologists and conservators from other subdisciplines such as underwater archaeologists and investigators working with anomalous preservation environments such as deep caves, peat bogs, or permafrost.

At CIL, remains are initially subject to accession activities and preliminary analyses that typically involve the removal of the material from its containers into a laboratory environment for about an hour. Analysts wear disposable latex examination gloves during these procedures. After a transitional period during which the use of gloves was strongly encouraged, this is now mandatory. At CIL it was found that archaeologists were typically less accustomed to the systematic application of infection control or the use of personal protective equipment and were initially less compliant with the recommendation to use gloves than staff members whose principle training and experience is in a clinical or forensic science. Results indicate that low levels of handling without gloves at this stage do not generally impact aDNA analyses. It appears that the months that elapse between these preliminary analyses and the sampling for aDNA testing suffice to permit any superficial contamination to decay to unproblematic levels. Handling without gloves in the days or weeks immediately prior to sampling for aDNA testing does represent a real risk and should be avoided. CIL has documented an example where ungloved handling of human remains a few days prior to sampling for aDNA testing resulted in a DNA sequence consistent with the scientist, to the exclusion of all other reasonable possibilities, and without so much as a trace mixture of a second species of DNA that could be attributed to the sample.

It seems that not all DNA is equally stable. The exact mechanisms are unknown, but the DNA inside the bones and teeth is somehow stable over many years, while the DNA contamination to the bone surfaces is much less persistent, perhaps because it has more exposure to the ambient UV light along with the oxygen and humidity in air. Further studies will be required to clarify this effect. Following preliminary analyses, remains are rebagged and resealed with the addition of more desiccant if warranted. The bags are stored in acid-free cardboard containers shelved within the laboratory, maintained at around 20°C. Damp remains are occasionally placed in a drying cabinet for approximately 24 hours, in which case they are spread out on disposable surgical napkins. Analysts may conduct odontological, anthropological, and radiographic analyses of remains prior to DNA sampling. Where this is the case, the identities of all individuals working on the remains are recorded so that, subsequent to DNA testing, their DNA profile can be compared to the test results in order to check for possible contamination. Gloves are always used to handle remains, but while reasonable care is taken to prevent other contamination routes, no other protective equipment is mandated at this stage. CIL scientists have also found that routine radiography of remains at this stage...
has no effect on subsequent aDNA potential. Analysts are encouraged to complete analyses in a timely manner so as to limit the exposure of the remains to the potential contamination of the laboratory environment. In general, it is CIL policy to obtain the DNA samples as soon as possible, once it has become apparent that DNA testing will be required.

On the day that remains are removed from storage to obtain samples for aDNA analysis, a much stricter regime of protective measures is implemented. The sealed bags are transported to the DNA sampling area. Bones are left in the bags during preparation for sampling. Sampling is typically conducted by two staff members. One person actually handles the sample (hereafter identified as the sampler), while the second person (the assistant) assists by minimizing the need of the sampler to touch anything other than the sample and decontaminated sample-cutting equipment. Both sampler and assistant wear clean surgical scrubs or a full-length disposable surgical gown. Both also wear one or two pairs of surgical gloves. When using two pairs of gloves, the inner pair of gloves serves to protect the user’s skin against the sodium hypochlorite (bleach) used liberally in the sampling environment, while changing and bleaching the outer pair protects the sample from the staff members’ DNA. Similarly, the use of surgical gowns or scrubs minimizes the input of human skin and hair to the sampling area and, by catching the inevitable sodium hypochlorite overspray, encourages generous use of bleach on all work surfaces. The sodium hypochlorite solution is made up in the laboratory from nine parts tap water to one part commercial bleach. The sampler also wears surgical sleeves if no gown is used. These serve to seal the area between the arms of the scrub top and the gloves, further preventing shedding of hair and skin residue into the sampling area. Surgical caps and masks are used for similar reasons. Eyewear of some sort is mandated for the individual cutting the sample to mitigate the risk of flying debris from the sample or the cutting blade. Eyewear also helps to prevent personnel from touching their eyes inadvertently. Humans tend to touch their eye area frequently, and the cells of the cornea have the highest turnover of any tissue in the body. Corneal epithelia are replaced every 6 to 24 hours with at least a portion of the dead cells sloughing into the environment. In addition, the prevalence of bleach in the aDNA sampling environment means that touching the face and eyes could cause bleach burns as well as sample contamination.

While the sampling, weighing, and photography areas are decontaminated prior to sampling, the cutting tool and cutting blades are “cross-linked.” CIL uses a Spectronics XL-1500 UV Crosslinker, delivering variable doses of short UV (254 nm) radiation. As the radiation is delivered from fluorescent bulbs at the top of the chamber, the UV radiation will not reach the underside of UV opaque objects unless they are raised off the bottom of the crosslinker on a UV transparent platform.

The sampling area used at CIL is a chemical fume hood manufactured in stainless steel with smooth welds at the joint surfaces and an adjustable glass sash window. CIL has further customized this hood by the addition of a short-wave UV flood lamp (254 nm). Prior to sampling, the interior surfaces of the hood and window are sprayed liberally with bleach and wiped down. The UV floodlight is turned on for five minutes to complete the process of decontaminating the sampling area. Weighing and photography areas are similarly prepared. Other touched surfaces such as the top of the cutting-tool power unit, the sill at the front of the hood, the external and lower surfaces of the hood sash, areas around switches and handles are all wiped with a towel moistened with bleach. Fresh gloves are donned after this surface preparation is completed, and the new gloves are wiped with bleach.

The element to be sampled is photographed and moved to the sampling area. The cutting tool is removed from the crosslinker, and the extractor fan on the hood is started. The fan is not run continually as this would merely serve to draw air from the external environment into the clean hood. During sampling the airflow serves to protect the sampler from smoke and dust. The principle here is that the sampler touches only the sample element and the cutting tools. All other activities are conducted by the assistant.

Once cut, the sample is weighed and photographed with the source element and with the sample transmittal envelope. The sample is
sealed into the envelope, which is also photographed, concluding the clean phase of the procedure. All areas are swabbed with bleach. Disposables, including the cutting blade, are discarded. UV is applied to the cleaned sampling area. The cutting tool is wiped with bleach and returned to the crosslinker for irradiation and the process starts over.

A similar process is used for sampling teeth, except that sampling surfaces are sprayed and wiped with bleach multiple times prior to each sampling. The low sample volume (typically around 500 mg) means that the risk of including a significant fraction of endogenous DNA is proportionately greater. Trace contamination that might be undetectable in a 5 g osseous sample could swamp the endogenous DNA signal from a 500 mg sample. In addition, unlike the osseous sample blocks, once the dentine is drilled, the resulting powdered sample cannot be further cleaned prior to DNA extraction. These factors combine to warrant more stringent anticontamination procedures for the dental samples. The risk that the sampling will be destructive (catastrophic failure of the tooth during drilling) is mitigated by presampling photography and radiography of sufficient quality for use in a forensic case report. The tooth is subject to ultrasonic cleaning in a sealed container of dilute bleach. The sealed container is moved to the sampling area before the tooth is removed and cut open below the crown. Dentine powder is drilled from inside the tooth root and beneath the crown (Smith et al. 1993; Shiroma et al. 2004). The powder is collected in cross-linked disposable weigh-boats, which are used to transfer the dentine to cross-linked, preweighed, 15 ml screw-top tubes. The tube is reweighed to determine sample mass, and the sealed tube is forwarded to the DNA laboratory for analysis.

Results of aDNA Testing:
The CIL Sample Population

Much of what follows is a discussion of a large series of aDNA tests on skeletal and dental remains believed to belong to unidentified U.S. military personnel. These remains were largely excavated from the battlefields of World War II, the Korean War, and Vietnam War. The oldest remains tested in this CIL sample population were those of an individual killed at Pearl Harbor on 7 December 1941. This is still just over six decades ago, somewhat recent as a model for most archaeological contexts. It emerges nevertheless, that absolute age of skeletal remains is not, of itself, an important determinant of success or failure in obtaining genuine DNA data.

A small fraction of the 2,172 osseous samples discussed here originate from remains turned over to the United States by foreign nationals and governments. The majority were excavated by CIL’s search and recovery teams from a highly diverse range of climates and contexts. Recovery environments stretch from tundra to jungle, Pacific Islands to Eastern Europe, the rice paddies of Laos to the valleys of North Korea. Recovery contexts include aircraft crash sites, both deeply impacted and surface debris scatters, infantry fighting positions, clandestine burials and marked graves, and sites in freshwater swamps. Altitudes have varied from saltwater muds below the tide line to the high mountain ranges of Tibet and Irian Jaya. Remains have been recovered from burned-out vehicles; others have lain buried in pockets of unburned fuel or in contact with metal objects since the time of death.

In many cases specific environmental and contextual factors are represented by too few cases to support meaningful statistical analyses. The sample pool discussed here is a very diverse one, representing the broadest range of depositional and taphonomic processes. The results of analyses of the pooled sample can be considered a broad generalization of what is and is not likely to be effective in the analysis of skeletal and dental samples. The statistics cited are more useful in determining the relative success rates of various subsets of the total sample than as a specific guide to absolute expected DNA sampling success rates. In any given archaeological environment, recovery of DNA may be more or less successful. In addition, the CIL sample pool represents a meta-analysis of a decade of casework. DNA laboratory procedures have improved during this period, but simultaneously the forensic anthropologists at CIL have submitted increasingly challenging samples for analysis. In cases where many skeletal and dental elements are available for analysis, CIL’s accumulated
experience has allowed judicious selection of samples, improving success rates. On other occasions, CIL has submitted samples where, a priori, it seemed that there was just a slim chance of a successful outcome. These latter cases have tended to deflate overall success rates, as have persistent failures in sampling and consequent repeated resampling from a small minority cases that have refused to yield their DNA, even after several attempts.

All samples in this study were subjected to mtDNA analysis. Although obtaining nuclear DNA from ancient material is significantly more challenging, nuclear DNA technology is advancing rapidly. There is no reason to believe that the relative differences in success rates presented here will not generalize to future nuclear DNA results. It is widely anticipated that recovery of nuclear DNA data from ancient materials will never be quite as successful as mtDNA testing due to the absolutely greater quantity of mitochondrial genomes in any given quantity of biological material. The mtDNA testing discussed focused on the sequencing of 611 base pairs of the hypervariable regions of the mtDNA control region. All mtDNA analyses were conducted by the mtDNA section at the Armed Forces DNA Identification Laboratory (AFDIL), following variants on the protocols outlined by Matthew Gabriel and colleagues (2001). For the purpose of this discussion, a simplification is made of the DNA results. Inconclusive sequence data and cases where no sequence data were attained are collapsed into a single category of failed samples. A minority of samples, where some meaningful fraction of the hypervariable region sequence was obtained, is pooled with the bulk of results where full sequence data was obtained. Together, these are considered the successful samples.

**Sample Submission to the DNA Laboratory: What to Sample and How Much?**

Following sampling, batches of samples are couriered to AFDIL where they are accessioned and stored frozen until scheduled for processing. Processing for the dentine powder starts with the initiation of the DNA extraction in the tube submitted. For osseous samples, a further decontamination step takes place in which the bone is mechanically sanded in a DNA-clean laboratory until all external surfaces are removed. All flaking, cancellous, diploic, or otherwise noncompact bone is sanded away. The resulting cleaned block of compact bone is washed and, if possible, subdivided to provide duplicate samples for subsequent steps in the analysis. Typically 2.5 g of prepared bone is used for each extraction. If the total mass of bone remaining after preparation is less than 0.5 g, the sample does not meet the criteria for submission to AFDIL's mtDNA testing program and is rejected. Less than 2% of samples were rejected on the grounds of insufficient residual mass.

Of the samples tested, 7% yielded no DNA data at all, while 22% yielded some DNA data that was either too sporadic to report as a result, was deemed invalid as a result of quality control failures within the DNA laboratory, or where multiple types of DNA were mixed in the same sample. Approximately 0.5% of the samples tested yielded mixed or unmixed DNA data that could be attributed with some certainty to the CIL scientific staff who had been in contact with the remains. A very small number of samples (0.07%) yielded reportable DNA results that appeared genuine but upon further analyses within each case were shown to be false positive results. The remaining 71% of samples tested successfully with interpretable data recovered. While this represents a baseline figure, it requires some further explanation. A number of factors are believed to contribute to the chances of success in aDNA testing. In this study, the specific element sampled, the mass of the sample, the age of the material, and the environment of deposition are all considered for their effect on aDNA recovery rates.

The most frequently sampled bone, the femur, is also the single most successful element with an overall success rate of 87%. As analysts at CIL are well aware that the femur generally yields good results, it is preferentially sampled, although it still only represents 14% of the total population of samples. When considering why the femur is significantly better ($\chi^2=47.5, df=1, p<.000001$), three principal explanations are offered: (1) femur samples are on the whole larger, and large samples in general have a greater chance of yielding a successful result; (2) the femur is a better source of samples for reasons independent of the size of the
Sample Mass and aDNA Testing Success Rate

Figure 1 presents a summary of the results for 2,172 osseous samples (excluding dentine samples) where all elements are considered and sample mass is plotted against probability of success. The line is derived (\(x\) coordinates) from a rolling average mass of 200 sequential samples drawn from all samples, rank ordered by mass, and the percentage successful samples (\(y\) coordinates) for each of these rolling subsamples. This estimates the point probability of a successful analysis at any given mass, essentially a yield curve for sample mass. It is apparent that there is a steep rise in sample success rate between 2 and 7 g of sample submitted. Beyond about 10 g, the success rate flattens out to an asymptote (plateau) at around 85%. The larger the sample, the greater the probability that it will be successful, particularly up to around 7 g, and with modest additional return per gram for heavier samples. This does not address the second potential explanation concerning element specific success rates.

Element Sampled and aDNA Testing Success Rate

If the same sample pool is divided by skeletal elements sampled, as detailed in Table 1, marked differences in success rate are seen. Although some of the element-specific success rates are derived from relatively small samples, there is a clear pattern. Elements in the lower limb are more successful than elements in the arms, which are themselves more successful that elements from the axial skeleton. Cranial samples are also much less successful than the mandible. A visual representation demonstrates this patterning across the skeleton (Figure 2).

It is evident that some skeletal elements are more successful than others and that there is also an overall increase in success rates with larger samples, but to what extent are these effects independent of one other? With all samples placed in rank order by weight, smallest first, the lightest femur sample does not occur until 192 samples into the 2,172 osseous samples. Of the 100 heaviest samples, 75 are femora. Figure 3 plots the yield for humeri and femora separately, using point estimates derived from groups of 40 samples. The plot shows that the relationship between sample mass and success rate is maintained within elements. In those areas where many samples of the same size are represented for both elements, there are large differences in success rates. Forty femora samples with a mean mass of 4.50 g have a success rate of 92.5%. In contrast, 40 humeri sample with a mean mass of 4.51 g have a success rate of just 75%. Not only does the humerus appear to be absolutely less successful...
TABLE 1
SKELETAL ELEMENTS SAMPLED

<table>
<thead>
<tr>
<th>Element Sampled</th>
<th>Number of Samples</th>
<th>Percent Successful</th>
<th>Median Sample Mass</th>
<th>Residual</th>
</tr>
</thead>
<tbody>
<tr>
<td>Femur</td>
<td>477</td>
<td>87</td>
<td>7.8</td>
<td>+4.2</td>
</tr>
<tr>
<td>Tibia</td>
<td>306</td>
<td>83</td>
<td>6.5</td>
<td>+4.1</td>
</tr>
<tr>
<td>Metatarsal 1</td>
<td>23</td>
<td>74</td>
<td>1.6</td>
<td>+16.1</td>
</tr>
<tr>
<td>Os Coxa</td>
<td>87</td>
<td>74</td>
<td>4.4</td>
<td>+1.8</td>
</tr>
<tr>
<td>Mandible</td>
<td>50</td>
<td>72</td>
<td>2.8</td>
<td>+22</td>
</tr>
<tr>
<td>Teeth</td>
<td>442</td>
<td>72</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Humerus</td>
<td>339</td>
<td>71</td>
<td>5.6</td>
<td>-2.0</td>
</tr>
<tr>
<td>Scapula</td>
<td>39</td>
<td>69</td>
<td>3.9</td>
<td>+2.2</td>
</tr>
<tr>
<td>Fibula</td>
<td>87</td>
<td>63</td>
<td>4.2</td>
<td>9.5</td>
</tr>
<tr>
<td>Rib</td>
<td>43</td>
<td>63</td>
<td>1.8</td>
<td>+3.0</td>
</tr>
<tr>
<td>Radius</td>
<td>101</td>
<td>61</td>
<td>4.0</td>
<td>-6.3</td>
</tr>
<tr>
<td>Vertebral</td>
<td>21</td>
<td>59</td>
<td>2.4</td>
<td>+3.8</td>
</tr>
<tr>
<td>Clavicle</td>
<td>56</td>
<td>58</td>
<td>2.6</td>
<td>+4.9</td>
</tr>
<tr>
<td>Ulna</td>
<td>111</td>
<td>57</td>
<td>4.0</td>
<td>-11.5</td>
</tr>
<tr>
<td>Other</td>
<td>97</td>
<td>52</td>
<td>2.7</td>
<td>+1.1</td>
</tr>
<tr>
<td>Cranium</td>
<td>197</td>
<td>47</td>
<td>5.9</td>
<td>-28.7</td>
</tr>
</tbody>
</table>

as a source of DNA samples due to the smaller average sample mass, but it seems to perform poorly in comparison with same-sized samples from the femur, gram for gram.

One way of visualizing this effect for many elements is to examine a plot of median sample weights for each element against element-specific success rates (Table 1). Figure 4 shows points plotted for 14 different skeletal elements and a 15th point for all other osseous samples, the majority of which are long bone fragments that were too degraded to make an absolute determination as to element. The line plotted as a reference with the points in Figure 4 is the yield curve for the whole sample, as in Figure 1, smoothed using the Lowess line-fitting function, an iterative locally weighted least squares technique, as implemented by SPSS statistical software (SPSS 2000). This line represents the expectation of success for a given sample mass based on all observed samples.

While the central part of this line represents a reasonable generalized estimate for the skeleton as a whole, femora and tibiae dominate the heavier samples. If the femora and tibiae are removed from the analysis, the yield curve shows lower success rates for heavier samples. The total sample yield curve demonstrates that some sample elements deviate significantly from the expected success rates derived from the overall relationship between success rate and sample mass. Femora and tibiae are, as expected, close to the yield curve for the total data set. This is unsurprising, as the vast majority of the data defining the upper portion of the yield curve comprises tibial and femoral samples. When the effect of these two elements is removed from the yield curve, it is clear that, gram for gram, the tibia and femur outperform the generalized yield curve for the rest of the sample. Elements falling below the yield curve are under performers. Notable amongst under performers are the 197 cranial samples: despite a median mass of 5.9 g, just 47% of these samples yielded reportable sequence data. Ulna, radius, and humerus are all below the yield curve, reinforcing the impression given in Table 1 that these elements yield relatively poor samples. Even after sample mass is taken into account, gram for gram, arm elements still under perform.

Near the curve is the “other” category. While “other” contains phalanx, calcaneus, manubrium, and other unlikely candidates for sampling, it is dominated (69%) by nondiagnostic long bone fragments. Many of these are probably derived from dense cortical fragments of tibiae or femora, which, as discussed above, are good sample sources. Nevertheless, the degree of weathering and/or fragmentation preventing
identification of the specific bone depresses success rates below those achieved for identifiable tibiae and femora. With median mass of just 2.7 g, the success rate of 52% is a reasonable performance nevertheless, suggesting that such superficially unpromising fragments might be a better sampling choice than identifiable skeletal elements from the cranium and upper body.

Table 1 also lists the residual between the expected success rate predicted by an element’s median mass and the overall yield curve (Figure 1) and the observed success rate (Table 1). Examination of Table 1 and Figure 4 shows
two unexpectedly good performers: the first metatarsal and the mandible. Samples from both these elements fall well above the yield curve. The mandible in particular is an extraordinarily productive sample achieving a 72% success rate on a median sample mass of only 2.8 g (n=50), 22% above the yield curve. Gram for gram, the first metatarsal is more successful than the mandible. First metatarsal median mass is lower, at 1.6 g (n=23), and the success rate is marginally higher at 74%. Although the mandible is only 16% above the estimated yield curve, the (empirically derived) curve itself spikes at this point. This further underscores the need to interpret the yield curve cautiously or to apply some smoothing function (such as that used in Figure 4) to the yield curve prior to using it for strictly quantitative analysis of residuals. Qualitative analysis suffices to show that, gram for gram, mandible and first metatarsal samples significantly outperform the bulk of the other samples.

It is worth noting that of 442 dental samples (mostly dentine powder) submitted for aDNA testing, 320 (72%) yielded sequence data. This places teeth amongst the most successful elements tested. What is more remarkable is that these results are obtained on sample sizes that are often less than 0.5 g and sometimes significantly lighter. Due to difficulties in accurately weighing the powder samples while simultaneously implementing extreme anticontamination measures, CIL has only accumulated limited data on the precise sample masses of the dentine powder samples. CIL has recently modified the sampling protocol for teeth and anticipates developing a more detailed statistical breakdown of the results of aDNA testing for dental material in the future.

Having shown that, amongst the nondental elements, heavier samples are generally more successful and that there are, in addition, marked deviations by skeletal element from this underlying relationship, the third question is posed: to what extent do depositional and recovery environments influence success rates of aDNA testing? If such effects do exist, are they correlated with the differential success rates observed by sample mass and element? In effect, are environments that are good for aDNA preservation also linked to preservation of skeletal materials that yield high sample mass and optimal choice of sample elements? One of the hazards of post-hoc analysis is that it can be difficult to tease apart correlation and causation. The following analyses go some way towards this for two major taphonomic factors: (1) elapsed time since deposition of the remains, and (2) prevailing climate.

**Time Elapsed Since Deposition of Remains and aDNA Testing Success Rates**

Time elapsed since deposition has generally been held to be an important determinant of the ease with which aDNA testing can be applied. Claims of extremely ancient DNA recovery from fossil remains have been met with skepticism in the biological community (Cooper and Poinar 2000), but no uniform temporal model of DNA decay can account for the sporadic recovery of aDNA from material within the plausible range of the technique. While time since deposition is always going to be seriously confounded by other factors influencing DNA preservation, it is certainly worth examining where a body of samples represents a range of ages. In this study, the material is drawn from a limited span of time, but because the entire time span is, archaeologically speaking, relatively recent, it offers an excellent test of a simple decay (or half-life) model for retention of recoverable aDNA.

The material considered here represents 1,945 samples assigned to three temporal categories, 1941–1945 representing casualties in World War II, 1950–1952 representing Korean War losses, and 1965–1975 representing the remains of those killed during the Vietnam War (Table 2). Korean War (n=558) and World War II samples (n=423) are equally successful; both have an overall success rate of just over 78%. The more recent material from the Vietnam War

<table>
<thead>
<tr>
<th>Conflict</th>
<th>Dates Represented</th>
<th>Number of Samples</th>
<th>Samples Successful (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>World War II</td>
<td>1941–1945</td>
<td>558</td>
<td>78.4%</td>
</tr>
<tr>
<td>Korean War</td>
<td>1950–1952</td>
<td>423</td>
<td>77.7%</td>
</tr>
<tr>
<td>Vietnam War</td>
<td>1965–1975</td>
<td>964</td>
<td>64.8%</td>
</tr>
</tbody>
</table>
War (n=964) lags significantly behind with an overall yield of just under 65%. Not only does this not support a simple half-life model for DNA retention but, contrarily, there is also statistical support for differences between the age categories ($\chi^2=43.3$, df1, $p<.000001$) where the youngest samples perform the worst. This approximate shortfall of 12% in average success rate between the oldest and youngest samples can be compared to the 39% difference in success rate between the best (femur) and worst (cranial) skeletal elements (estimated on a weight-corrected basis).

To what extent is the superior performance of the older samples due to poor representation of the optimal skeletal elements in the Vietnam War sample? Of the pre-Vietnam samples 42% are either from tibiae or femora. In contrast, just 29% of the Vietnam-era samples are drawn from these elements. Recalculating the expected values for the $\chi^2$ test using elementspecific expectations (based on their performance in the overall sample) reveals a subtly different result. The null hypothesis that after correcting for the representation of skeletal elements, the success rates of the chronological sub-samples are equal is still rejected. A significant difference between the success rates of the three subsamples remains. There is a marked reduction in the magnitude of the effect: $\chi^2=16.2$, df4, $p=.0003$. This clearly remains significant but translates to a reduced difference in success rate (to just under 9%) between the best-performing samples (World War II) and the worst (Vietnam era).

**Climate and aDNA Testing Success Rates**

To the anthropologists and archaeologists leading the U.S. military’s search and recovery teams in Southeast Asia, the reasons for the elevated levels of aDNA testing failures for Vietnam-era material seem obvious. It is widely held that the climate is to blame. The heat and moisture, coupled with the vigorous growth of plants and microbes are believed to specifically promote the decay of endogenous DNA and generally contribute to the breakdown of the human remains. There is a rather obvious, albeit somewhat crude, test of the strength of this climate-based hypothesis for DNA loss: a simple comparison of success rates by climate. Elaborate tests of the effect of different climatic variables could be implemented and will likely be the subject of future research. For the purposes of this review, samples were divided into tropical and temperate recovery environments. Some simplification is unavoidable, and some recovery environments are excluded completely from this test as they do not easily classify into either climate category.

<table>
<thead>
<tr>
<th>Table 3: Division of Recovery Locations by Climate</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Temperate</strong></td>
</tr>
<tr>
<td>Belgium</td>
</tr>
<tr>
<td>China</td>
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Table 3 lists the major and minor contributors to the two climate categories.

As expected, samples drawn from elements deposited and recovered in tropical environments are less amenable to aDNA analysis (Table 4). With sample sizes of 1,228 for tropical environments (822 successful) and 771 for temperate (585 successful): $\chi^2=18.1$, df1, $p=.0003$, translating to a 9% shortfall in success rate for tropically recovered samples. Nevertheless, variables already established as strong indicators of aDNA
testing success are not themselves independent of climate. The temperate recoveries represent just 38% of the 1,999 samples considered, but 45% of the 717 femur and tibia samples considered are from temperate recovery environments. Once again, generalized element-specific success rates are used to produce a modified expectation under the null hypothesis that, after accounting for elements tested, there is no residual difference in success rates by climate. Under this element-corrected test, the apparent effect of climate is greatly ameliorated although still significant: \( \chi^2 = 6.5, df = 1, p = .001 \). This latter effect corresponds to a difference in success rate of a little over 5%. On average, 1 in 20 samples that would have worked from a temperate environment will fail in tropically recovered skeletal samples from the same element. This is a weaker effect than that seen when the samples are divided by conflict, and much weaker than the differences seen between elements within the skeleton. A harsh climate in and of itself is not an obstacle to aDNA recovery from skeletal remains provided that an adequate mass of compact bone sample is obtained.

**Discussion**

As the field of aDNA grows and the newly developed technology becomes routinely available, archaeologists will increasingly need to make judgments about the feasibility and utility of aDNA studies as a component of the postexcavation analytical process. In addition, those executing such studies will benefit from baseline empirical data indicating what is likely to work best, the relative merits of different sampling protocols, and the extrinsic factors that influence them. This study reports the data accumulated by CIL on recent historic material derived from military casualties whose bodies were not recovered at the time of their respective conflicts. These remains have been exposed to a wide range of environments and their concomitant taphonomic effects.

As discussed at the outset, the absolute figures presented here may or may not be directly applicable to any given archaeological problem. The skill and efficiency of the DNA laboratory and the effectiveness of sampling procedures in eliminating the introduction of contaminating DNA clearly factor into any analysis of absolute success rates for aDNA testing. As potential users of this technology, archaeologists should consider the expectations and pitfalls outlined here and be prepared to safeguard their DNA samples. This review is not intended to be a hard and fast blueprint for archaeological aDNA sampling. It provides methodological context for the results presented and also illustrates an approach that has produced useful results for CIL’s purposes. Just as CIL recognizes that the anticontamination needs of the osseous and dental components of its sample pool are different, specific archaeological projects may merit modifications of the sampling procedures.

Although it was assumed a priori that climate was a major component in aDNA preservation and decay, climate appears to be a weaker influence than several other important factors identified in this study. The general subdivision of samples into tropical and temperate recovery environments shows just a 5% differential in success rate against a baseline success rate of 71%. It may be that the dichotomous classification used is too crude to capture underlying effects of climate. Further analysis of soil and vegetation type as well as the ranges and means of precipitation, humidity, and temperature are clearly warranted. Such analyses may yield more strongly predictive models for aDNA success rates based on depositional environment.

It has generally been held that extremely arid environments promote the preservation of aDNA, but the mechanism is likely to be the same one outlined here. Extreme aridity retards virtually all biological activity. By preventing the general decay of biological integrity, extreme aridity will protect aDNA by physically protecting the remains. The results presented here suggest that it is unlikely that aDNA is specifically preserved by aridity above and beyond the level suggested by the macro preservation of the remains. Similarly, cave environments often represent very stable temperature and humidity regimes that can promote both the long-term physical integrity of remains and secondary mineralization of osseous and dental tissues. The CIL sample does not contain sufficient material from cave environments or extremely arid recovery scenes to directly address the question of special preservation under such conditions. It is predicted on the basis of the results presented here that indicators of macro preservation such as sample
mass, sample density, and surface preservation will adequately account for any variance in sample success that might be demonstrated from such environments. There is one important caveat to this prediction, and it concerns chemical preservation of remains. CIL has a few instances of casework samples where extreme chemical preservation is suspected (possibly the immersion of largely defleshed, skeletonized remains in formaldehyde-based embalming fluid for a period of several days). In these cases the physical preservation of the remains is macroscopically excellent. Nevertheless all attempts to extract amplifiable DNA have failed. The competing explanations are that either the chemical preservation has penetrated the bone and rendered the DNA nonamplifiable directly or that the chemical preservation has made the bone matrix so resistant to digestion that the treatment required to dissolve the bone is now so harsh that it destroys the DNA content even as the bone is digested. Research continues on this issue.

Similarly, although time since death was also considered, a priori, to be an important determinant of the survivorship of recoverable aDNA, there is no evidence at all of this effect in the samples available. Although the oldest of these samples dates only as far back as 1941, if there were a steep and systematic drop-off through time in the amount of aDNA preserved (a DNA half-life), it should have been detected as the older samples are approximately twice the age of the youngest. Nearly all other taphonomic factors have a cumulative effect through time, making it inevitable that much older archaeological samples will become progressively harder to work with. On the other hand, the lack of any detectable effect over the past 60 years suggests that as long as bones are well preserved and optimal elements well represented, aDNA testing will be relatively unproblematic over time spans of hundreds of years, certainly encompassing the entire span considered by historical archaeologists.

The fact that the youngest material in the CIL sample performed the worst is probably an effect of depositional taphonomy. The nature and machinery of warfare changed significantly between World War II and the Vietnam conflict. A collection of factors have combined to make the perimortem trauma associated with CIL cases from the Vietnam era much more severe and recovery of skeletal elements less complete than seen in either the World War II or the Korea cases. It seems likely that increased perimortem trauma and the increased postmortem taphonomic damage to the remains as a result of the trauma is the cause of the aDNA shortfall in Vietnam-era material. While there may be an underlying effect by sample age, this is completely swamped by differential preservation, even after the suboptimal selection of elements available for sampling is accounted for.

Since this statistical study was conducted, CIL has cooperated in sampling Civil War cases, and remains were submitted to AFDIL. Initial results from the remains recovered from the wrecks of the CSS _H.L. Hunley_ and the USS _Monitor_ have yielded excellent mtDNA data. The data reported to date (9 successes from 9 osseous samples, 8 successes from 10 dental samples, 1 staff-member contamination, and 1 inconclusive result) underlines the twin conclusions: where physical preservation is good, age is no bar to successful aDNA analyses (89% success rate for these two cases), and contamination with contemporary human DNA is always a risk in any archaeological aDNA project.

The CIL aDNA study indicates that selection of sample element is one of the most critical factors in determining a successful outcome in aDNA testing. Femora and tibiae are the best sources of skeletal samples, but amongst other useful elements, the _os coxae_ and the first metatarsal also deserve mention. Between them, these four elements represent the lower limb structures. These structures are maximally stressed both by the bearing of static body weight and the forces generated in locomotion. As a result, these elements have particularly dense cortical bone, and it may well be this factor that accounts for the improved retention of recoverable aDNA. While the _os coxae_ may seem an exception to this, the samples, which are typically cut from the ilium, do show well-developed cortical bone, particularly in areas of muscle attachment. The nonweight-bearing arm elements are not as successful as the leg elements, and the elements of axial skeleton are also generally poor. The scapula is the exception here, and its modest success is probably the result of the preferred sampling site on the axillary margin, slightly below the glenoid fossa.
where the scapula is particularly robust. Recent reassessment of vertebrae and rib samples has led to revised techniques focusing on areas of high bone density. This has yielded large apparent improvements in the success rates for these elements. Relatively little data is available so far, and this does not cover the full range of CIL casework. As such, it is hoped that these results will be reported in more detail in a future study.

Cranial remains are by far the worst source of samples. One of the more plausible explanations is that the cranium lacks areas of readily sampled, well-developed cortical bone, and where there is cortical bone, it is not very dense. Samples are generally cut from the parietal, but the occipital and frontal are also frequently sampled. In all these samples a significant component of the sample is diploe, which as noncompact bone is removed during the secondary decontamination preprocessing at the AFDIL. Clearly this leads to a major reduction in the residual sample mass available for testing. While the wisdom of discarding the diploic fraction has been questioned, the inability to properly clean and decontaminate the noncompact material, has led the DNA Laboratory to resist moves to process cranial samples without reducing each sample to compact bone fragments with completely sanded surfaces. Nevertheless, a program of testing cranial samples without discarding the diploe was initiated. CIL is selecting cases where the sample was cut as a window from an intact, uncompromised portion of the cranium. The cut surfaces of diploic bone are unexposed to potentially contaminating environments until the sampling event. While the wisdom of discarding the diploic fraction has been questioned, the inability to properly clean and decontaminate the noncompact material, has led the DNA Laboratory to resist moves to process cranial samples without reducing each sample to compact bone fragments with completely sanded surfaces. Nevertheless, a program of testing cranial samples without discarding the diploe was initiated. CIL is selecting cases where the sample was cut as a window from an intact, uncompromised portion of the cranium. The cut surfaces of diploic bone are unexposed to potentially contaminating environments until the sampling event. To date, insufficient sample volumes have been processed to make a final determination, but preliminary results suggest that, at best, there is no difference in the success rate if the diploic bone is included in the material from which DNA is extracted. When further data has been accumulated, a final determination will be made on optimal sampling and processing strategy on the cranium.

In marked contrast to the cranium, the mandible is an exceptional source of DNA samples and stands out as the only bone element above the waist that yields a success rate in excess of the 71% average yield. This is all the more remarkable when the low weight of the mandible samples is considered. Samples are typically cut from the inferior border of the body of the mandible, posterior to the mental foramen but anterior to the notional coronal plane passing through the mandibular notch. Analysts cutting samples here report that the bone is very dense. It may be the density of the mandible (an adaptation to the stresses of mastication) that protects the endogenous DNA in these samples. Further work specifically examining bone density is already in hand. An alternate explanation is that areas of reworked bone are particularly good sources of aDNA as living cells are entombed in the involucra formed by the ossification of secondary bone growth. The extreme resorption of bone seen in the mandible in the absence of marked masticatory activity (in edentulous individuals) implies that masticatory stresses are critical to maintaining cortical mass and bone density in the mandibular body of normal individuals.

Anecdotal evidence indicates that the relatively high success rate of samples taken from the os coxae is at least in part explained by the high DNA yields obtained from the iliac crest, but this has not yet been explicitly tested. If true this would certainly support the hypothesis that reworked cortical bone is a good source of aDNA as the muscle attachments on the iliac crest regularly produce a marked area of reworked bone. Other areas of the skeleton manifest normal nonpathological patterns of bone remodeling, and these could be systematically targeted in future studies. The forensic significance of pathological bony lesions, traumatic or otherwise, probably precludes systematic DNA sampling where several grams of bone are still required. There seems little to be gained by investigating the sites of such lesions for aDNA potential. Even if they proved a good source of aDNA, their utility for other forms of analysis argues against their destructive sampling.

Conclusions

A broad range of possibilities is presented to archaeologists by the emerging technologies of aDNA analysis, particularly those dealing with the more recent past. The application of the
technology is by no means routine, and even within the discipline itself there is still considerable debate as to appropriate procedures (Cooper and Poinar 2000). Nevertheless, as forensic standards of evidence are increasingly coming to be applied to the execution of aDNA testing, the interpretation of results is becoming relatively straightforward. The CIL sample provides some baseline expectations for sample sizes required and the chances of success for various skeletal elements and certain recovery contexts. It further establishes that absolute age does not, in itself, present an impediment to aDNA sampling where preservation and physical integrity of the sample elements is otherwise good. Our experience with ancient soft tissue, hair, and fingernails is insufficient to warrant analysis here, although human hair has been shown to routinely contain amplifiable mtDNA. Anne Stone, James Stars, and Mark Stoneking (2001) showed that in some environments hair can be superior to bone as a source of DNA. CIL cases do not typically offer many opportunities to work with human hair, and it is hoped that historical archaeologists who are likely to encounter hair more frequently will be able to build a knowledge base concerning aDNA and hair to fill this gap.

Similarly, CIL has limited data to suggest that fatty tissue residue associated with skeletal remains is also a good source of aDNA, but at this stage it can only advise historical archaeologists that fatty tissue residue is a potentially useful aDNA sample, and one that they might want to consider if destructive sampling of hard tissue was not permitted or is otherwise particularly undesirable.

With nearly 10,000 U.S. military personnel from the Korean and Vietnam wars yet to be identified, the CIL aDNA project will continue for the foreseeable future. Further research concerning the effect of bone density, bone histology, metal ion contamination, and soil chemistry on aDNA testing are under consideration, and new technologies continue to be assessed as they become available. CIL will continue to keep its DNA policies under review in the light of the accumulated data, and work is progressing on a multiple-regression-based model to better account for aDNA preservation.

Given the current state of the aDNA field, it would be a serious mistake to treat aDNA testing as a black-box technique, best left to molecular biologists in their hi-tech laboratories. It is hoped that this necessarily cursory overview of the current state of aDNA analysis along with the review of the CIL’s casework results will prompt archaeologists to engage the aDNA community in developing tests and protocols that will answer the questions that only they as archaeologists can properly frame. Given the growth of aDNA applications in archaeology, it is more than possible that aDNA research and development directed towards uniquely archaeological problems, rather than the needs of forensic science, will provide the next breakthrough application in aDNA testing.

Acknowledgments

This work was supported by a fellowship from the Oak Ridge Institute for Science and Education (ORISE) program. I would like to acknowledge Ann Bunch and Helen Wols for supporting this project. This work has benefited from discussion with AFDIL scientists, particularly Suni Edson, Chris Los, Jakie Raskin-Burns, Christine Boyer, Suzanne Barritt, Tom Parsons, and Brion Smith. Sheryl Shigeta, Ruby Jones, and Sardiaa Plaud all contributed to the preparation of the data and the manuscript. I would also like to acknowledge all those service members who gave their lives in war but whose remains have yet to be identified. Many of them are represented amongst these samples, and I hope that this study can in some measure contribute to their final identification and burial. The opinions herein are those of the author and do not constitute the official position of the Joint POW/MIA Accounting Command or the Department of Defense.

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Search for the Grave of William Preston Longley, Hanged Texas Gunfighter

ABSTRACT

William Preston Longley was one of the most notorious outlaws in Texas when he was finally tracked down, arrested, and convicted for shooting a boyhood friend. Since he had cheated death before, contemporaries easily believed Longley’s hanging in October 1878 was a hoax that allowed him to live and raise a family in Louisiana under an alias. The ultimate test of the hoax hypothesis would be to find Longley’s grave and expose either his remains or a weighted coffin. In fall 1992 and spring 1994, a team of scientists used electrical resistivity and magnetometer surveys to locate unmarked burials in areas where historical research indicated Longley’s grave may be located. Team members hoped a grainy historic photograph of the marked gravesite could be correlated with a position in the cemetery. The team determined the approximate location of an unmarked grave that could be Longley’s. Excavation uncovered the remains of a tall white male, which fit his description, and artifacts recovered from the grave were consistent with those known to have been buried with Longley. Finally, a mitochondrial DNA comparison with his living maternal relative produced a very high probability match.

Introduction

As outlaws of the early West go, William Preston Longley (Figure 1) was one of the deadliest, credited with more killings than Jesse James, Billy the Kid, or Wild Bill Hickok (Tillman 1998). A “handsome deceiver” and “ruthless pistolman” (Ripley 1935), Longley’s reputation for killing won him the nicknames of “Wild Bill” and “Bloody Bill.” His 6-foot height made him “Big Bill” (St. Louis Globe-Democrat 1878; Bartholomew 1953). His life even became the basis of a 1950s television series, The Texan, starring Rory Calhoun. His death inspired many stories that have endured to the present.

Bill Longley’s outlaw career began at age 17 in tumultuous post-Civil War Texas when he shot a black man in the head for brandishing a rifle and cursing whites in his path (Trachtman 1974). Known as a deadly accurate, quick-draw artist able to shoot well with either hand, Longley became the first “two-gun” outlaw (Taylor 1926). His speed and accuracy, coupled with his violent temper, made him extremely dangerous—especially when insulted. For example, in the late 1860s it was rumored that he quickly killed a Yankee soldier who commented that “all Texans were thieves” and “there are no virtuous women in Texas” (Taylor 1926:21). Although wanted by the U.S. Army “dead or alive” for $500 in Texas, he enlisted at age 18 in Company B of the U.S. Second Calvary in the Wyoming Territory under his true name on 22 June 1870 (Ellison 1995). He deserted on July 3 and was captured the following day.

FIGURE 1. William Preston Longley (1851–1878). (Photo from Douglas W. Ellison personal collection.)
After spending five months in the guardhouse, he returned to Company B and served just short of two years until he again deserted on 8 June 1872 and returned to Texas. His marksmanship with a pistol was described as second to none by a fellow soldier (Gross 1877).

As a desperado, Longley turned into a drifter. Conflicting reports claimed he roamed to the Utah Territory, or lived with the Ute Indians, or served time for murder, using various aliases. Back in Texas, while commissioned as a deputy under an assumed name, he killed William (Lou) Shroyer in 1876 in a running gun battle (Taylor 1926). Six months later, under another alias, Longley ambushed and killed the Reverend Roland Lay, who was milking a cow, because Lay had recommended that Longley stay away from a daughter of Lay’s neighbor, Longley’s first love interest (Taylor 1926; Miller 1999). All told, rumors held Longley responsible for the deaths of 32 men and 1 woman (Houston Daily Telegram 1878; Taylor 1926; Miller 1999). Once, it is reported, vigilantes hanged Longley along with a horse thief, but when the departing hangmen fired a volley at the dangling bodies, a bullet cut the rope, suspending Longley, and he survived (W. Longley 1877; Killen and Vance 1974).

Longley was finally captured in Louisiana and convicted of killing a boyhood friend in Giddings (Figure 2). During his time in prison he repented his crimes and converted to Catholicism (Killen and Vance 1974). Hours were spent writing letters to local newspapers about his life. In an appeal to the governor, he complained that his death sentence was unjust as compared to Texas’ most notorious gunfighter, John Wesley Hardin, who had recently been given only a long prison term. According to Longley’s guards, he only once briefly lost his composure when his niece, age 10, visited him a few hours before the hanging and placed a flower in his lapel (C. Longley 1878; St. Louis Globe-Democrat 1878; Bartholomew 1953).

When he faced the gallows on 11 October 1878, having admitted to only eight killings, he was 27 years old (Miller 1999). At his execution he wore a good suit and smoked a cigar, having written a childhood schoolmate: “Hanging is my favorite way of dying ... I would rather die that way than any other way on earth, that is except a natural death ...” (W. Longley 1878; Hunter and Rose 1951:78). He joked with his executioners, asked the crowd of 4,000 onlookers for forgiveness for his wild, reckless life, bowed his head for a priest’s prayer, and listened while Sheriff Brown read the last words of the sentence handed down by the court: “To be hanged by the neck until dead, dead, dead” (Rummel 1926:11). Sources say he wore a black suit, a fine white shirt with a turndown collar, a black necktie, and a blue rosette in his lapel (St. Louis Globe-Democrat 1878).

When the trap door opened, the rope slipped on the beam. Longley did not hang but, instead, dropped for a distance of 12 feet, falling to his knees (Galveston Daily News 1878; Cunningham 1941). As he fell, “a heavy piece of iron rail” under the platform dislodged and “hit Longley’s legs with full force” (Rummel 1926:11). He was quickly lifted from the ground, and the rope was pulled taut. After this second attempt and a time lapse of 11 minutes,
he was pronounced dead and placed in a plain pine coffin. The lid was screwed down, and the coffin was taken for burial outside the boundaries of consecrated ground at the cemetery west of town (St. Louis Globe-Democrat 1878; Killen and Vance 1974).

Rumors began immediately that the initial hanging attempt failed because accomplices had attached the noose to a special harness Longley wore that prevented his neck from breaking. Comments by Campbell Longley (Bill’s father) and Hiram Craig (a sheriff’s deputy) imply that the hoax was a ruse to help Bill’s traumatized mother deal with the loss of her son (S. Longley 1878; San Antonio Daily Express 1887; Robinson 1932). As recently as 1987, a relative of Longley’s built a gallows, donned a home-crafted harness, hanged himself and lived to prove that Bill could have survived (Herman 1987). Longley’s coffin was supposedly filled with rocks wrapped in a rug while he allegedly escaped on the way to the cemetery (Bartholomew 1953). Since then, various tales claimed he became a cattleman in Nicaragua, was a passenger on the Lusitania when it was sunk, or escaped to Mexico where his grandson became a provincial governor.

Another story claimed Longley escaped to Iberville Parish, Louisiana, where he lived and raised a family under the assumed name of Captain John Calhoun Brown (Wax 1988). Since the sheriff of Giddings, who supposedly helped Longley escape death, was named Brown, this alias seemed plausible. A grandson of Captain Brown, Ted Wax, learned of the possible connection to Longley and interested Douglas Owsley in the story. A computer-based comparison of photographs that Wax had of Longley and Captain Brown left the possibility that the two were the same man (Hammer 1992). Handwriting comparisons also suggested that Brown and Longley were the same individual (Wax 1988). Did renegade Bill Longley die at the gallows as three doctors attested? Or did he survive as an upstanding citizen and businessman to die in old age mourned by many friends?

Previous Work

Locating Longley’s unmarked grave in Giddings and revealing the coffin’s contents would resolve these historical questions. A Texas Historical Commission marker, placed in 1976 at the city-owned cemetery, only indicated that Longley was buried in the Giddings cemetery. According to historical accounts, Longley’s grave initially was marked by a blackjack oak tree; it was only in the early 1920s, after the tree died, that a headstone of petrified wood about 18 in. tall was erected (Taylor 1926). This headstone was reportedly moved at least three times between 1925 and 1945, and later stolen, but replaced with a similar piece of petrified wood in 1978 (Kenneth Ahlschlaeger 1992, pers. comm.). It was alongside the recent headstone that the historical marker was placed. Because only the headstone was moved and not the coffin, the original grave location was lost.

The Giddings cemetery continued in use and, over the years, expanded through purchases of additional land. Empty land once outside the 19th-century cemetery is now not only within the boundaries but also filled with graves. Assuming that the moved marker meant the grave could be almost anywhere outside the old perimeter, six areas (based on recollections of elderly citizens, cemetery records, and geophysical surveys) were identified as potential locations for Longley’s grave.

In August and September 1992 and in March 1994, a total of 34 unmarked graves were identified, and 21 were tested. Not one of the burials was filled with stones, and no white male in his 20s was found within the 21 graves. For a complete discussion of the electrical resistivity and magnetometer surveys of the cemetery, as well as the resulting excavations, see Brooks B. Ellwood et al. (1994) and Douglas W. Owsley et al. (1994).

Photographic Research

Various references state that Longley’s grave was outside the boundaries of the cemetery in 1878, but the only direct evidence of the grave’s possible location is a grainy, poor-resolution, undated photograph taken by an amateur photographer, William E. McIntire, showing a piece of petrified wood ostensibly marking the grave (Figure 3). After unsuccessful attempts to find the grave in 1995, research focused exclusively on the historic photograph.

A photographic expert at the University of Texas-Arlington, Chuck Pratt, concluded that
the image was taken in the late 1920s or early 1930s. In an article published in the 1920s, T. U. Taylor (1926:30) stated that the petrified wood grave marker was placed “within the last few years.” The Houston Post reported on 5 September 1937, “today Bill Longley’s grave is almost in the very center of that cemetery.” The photograph, showing the gravesite on the far edge of the burial ground, was probably taken after 1920 and before 1937.

Yet the photograph created many interpretive problems, including the obvious presence of a grave mound near the petrified wood marker. A mound of fresh dirt with no ground cover of grass or weeds could not have persisted for the 40 or 50 years between the burial and the photo. The soil would have subsided, eroded, and re-vegetated. Perhaps the photographer created a new mound for journalistic impact, or the mound represented a more recent burial. In any case, it was plausible that the photograph did not show the actual burial site of Longley.

Further complications resulted from the actions of the longtime cemetery caretaker, Martin Placke, who acknowledged having moved the petrified wood marker at least three times. Placke, who died in 1965, served for more than 50 years as the president of the Giddings Cemetery Association and assumed active management of the cemetery around 1925. His first survey of the cemetery showed that the Longley marker “was placed right on the boundary line, so they just moved it a short ways” (Socha 1991). Presumably, that move occurred several years after Placke became manager.

Later, Placke moved the marker a second time as the local paper noted: “The headstone was moved by Martin Placke at the request of the Catholics, mostly Hispanic, who were then using that once vacant area. Placke assures everyone that they did not move the coffin, only the stone, during his tenure as head of the cemetery association” (Lee County Weekly 1987). No date is given for this move. Even later, Placke moved the marker once more. This time, because it was in the path of a north-south road proposed in the 1950s, the marker was moved west (Killen and Vance 1974). No mention is made as to how far the marker was moved.

Since Placke did not move the coffin along with the marker, the initial conclusion was that the grave had been lost. It was possible
that Placke had moved the marker only short
distances around the general area of the grave.
If that was the case, perhaps the ca. 1930
photograph, devoid of marked graves, showed
the original location of Longley’s grave before
circumstances necessitated moving the petrifi-
ced wood marker.

The cemetery’s continued use resulted in the
installation of hundreds of new headstones, grave
curbing, power poles and lines, and even a new
road around the historical marker. Trees grew
and died, wild areas became mowed grass, and
new bushes softened hard angles of old tomb-
stones. Even the tombstones in the original
photograph are likely to have changed their
appearance. Some were probably replaced or
modified; others subsided into the ground, chang-
ing their profiles; still others broke, discolored,
or toppled. Recognizing the bucolic site of the
historic photograph hidden within the congested
contemporary cemetery seemed impossible, yet it
was critical to match the two in terms of topog-
raphy, trees, and burial markers. One constant
remained: the distinctive, near-horizontal horizon
line. In the Giddings cemetery, the terrain varies
from gently rolling to flat. Considering the size
of the cemetery, there are relatively few views
toward a flat horizon.

Based on shadow angles and lengths, as well
as the dry vegetation in the historic photo, Sue
Ellwood determined the season of the year
(fall) and the time of day (afternoon) at which
the photo was taken. A currently available
wide-angle lens similar to those available in
the 1930s was used to photograph the modern
cemetery. Recognizing that graves in most
Texas cemeteries are oriented east-west with
headstones at the west (Lebo 1988; Ellwood
1990), the historic photograph was probably
taken facing north.

To identify cemetery areas for photography,
the historic photo was scanned into a computer
to produce a high-resolution digital image.
Using available commercial software, sections of
the photograph were magnified and examined in
detail. Several distinctive headstones, including
a white cross, were identified along with a fork-
shaped tree, other trees, and unique headstones.
In an effort to match them, photographs of
different sections in the modern cemetery
were taken. Ultimately, a photograph taken
from a site near the current Longley historical
marker resulted in an image encouragingly like
the historic one. Using image enhancement
software, all tombstones with a date after 1935
were digitally removed from this new photo.
Also eliminated were bushes, curbing, a road,
and a pole with power lines. After adjusting
the scale of the digitized historic photo and
allowing for a slight difference in viewing
angle, several similarities between the images
became apparent (Figure 4). Three trees and
at least five tombstones with interment dates
of 1918 to 1929 were spatially aligned in the
correct horizontal distribution. These markers
have distinctive shapes, heights, and color
effects (corresponding light and dark areas
determined by the shape and type of stone)
that are recognizable with magnification of the
historic image. Potential discrepancies could be
resolved. On-site investigation revealed that the
white 1923 cross in the historic photo is higher
in the modern photograph because it had been
attached to the top of a modern black tombstone
of a family member (Figure 5). Two other
markers in the historic photograph have been
replaced by visibly newer styles following the
death of a spouse.

Based on this new photographic evidence, a
site 8 ft. north and east of the historical marker
was probed with a sediment-coring tool, which
confirmed the presence of mottled soil known to
be indicative of grave fill. There was no surface
indication of this burial, such as a depression,
as overlying fill was likely redistributed when
concrete coping surrounding an adjacent family
plot was prepared. Whether Longley, someone
else, or rocks occupied the grave could only be
proved by excavation of the gravesite.

The Excavation

The Texas Historical Commission gave per-
mission to excavate this site with the under-
standing that initially the skeleton would be
examined in the field. If the remains did not
conform to expectations, excavation would stop
and the grave would be returned to its original
appearance.

On 11 July 1998, as during previous excava-
tions, a skilled Bobcat operator maneuvered the
1.5-m backhoe blade to scrape away the topsoil.
As a result of extreme drought conditions in
Texas that year, soil characteristics typical of
a grave were not immediately apparent. Prior experience had shown that the grave shafts, being lighter in color than undisturbed soil, are usually easy to detect after removing several inches of overlaying topsoil. Despite initial bewilderment, the excavation carefully continued until five coffin nails were detected at a depth of 32 in. Excavators then shoveled down by hand to 36.5 in. where a coffin sideboard was delineated. At this point a rectangular-shaped grave outline could be seen, and fine silt was being recovered from inside the upper level of the coffin. While many nails and some screws were recovered from the grave, there were no metal handles or fittings; the coffin was a plain, hexagonal box (Figures 6a and 6b). Previously examined burials in the cemetery from this general time period contained decorative coffin hardware, including curved swing bale and short bar coffin handles, thumbscrews and escutcheons, caplifters, ornamental tacks, cuprous or silver-plated coffin plates, and sometimes glass viewing plates (Owsley et al. 1994).

The first bone segments recovered from the chest area indicated that the grave was oriented normally (west to east) for this cemetery. Since Longley was an outlaw, there had been speculation that he was buried not only outside of consecrated ground but also in an unusual orientation: north-south or with his head at the eastern end of the shaft (Jordan 1982). Some even suggested he might have been buried face down. This body was supine; the head was at the western end of the shaft, facing east. The remains were of a young adult male in his twenties who was tall and linear. The skeleton measured 180 cm (5 ft. 11 in.) from the top of the skull to the bottoms of the calcanei. Both arms were flexed at about 130 degree angles at the elbows with the hands prone (palmar surfaces down) and resting on the upper pelvis. Also found were stacked leather heels common
Longley’s physical appearance was well documented from “wanted man” descriptions disseminated among sheriffs. He was described as “about six feet high; weighs 150 pounds; tolerably spare built; black hair, eyes, and whiskers; slightly stooped in shoulders” (Taylor 1926:26). A reporter covering the execution provided the following account:

In person he was of the medium size, inclined to be slim, but evidently of compact muscularity. He did not present the aspect or idea of great bodily strength. His features tended to the Greek model. A pair of keen black eyes, perfectly alive with expression, were in keeping with the dark hair, cut in country style, and the black mustache and goatee. His nose was Grecian, and his teeth—beautifully white and faultlessly regular—were a prominent feature of a countenance that would be pronounced handsome by any woman in Texas (Houston Daily Telegram 1878:1).

Longley himself provided information about two physical anomalies that might be used to identify his remains, although Longley was known to exaggerate freely in his stories. In describing his first hanging, Longley said a bullet fired by the vigilantes went through his jaw, breaking a tooth (W. Longley 1877). Photographs of Longley taken at his capture and shortly before his execution show no evidence of the disfigurement. In another story, Longley claimed a bullet broke a rib that then protruded from the bullet hole in his chest (Fuller 1929). Either of those wounds would show up on bone if the elements were preserved.

**Osteological Assessment**

Correspondence in the age, sex, race, and approximate height of the remains in the coffin with that of Longley indicated that comprehensive laboratory analysis was warranted. The skeleton was completely excavated and transported to the National Museum of Natural History. It was in fair condition with partial preservation of the skull, scapulae, right clavicle, sternum, left innominate, diaphyses of the long bones, patellae, and the bones of the hands and feet. The vertebrae and ribs were fragmented. The only long-bone joint surfaces preserved were those of the distal right humerus, and the proximal left and distal left and right femora.

Evaluation using osteological and forensic anthropological criteria identified the remains as that of a tall male, aged 25 to 29 years, of European ancestry. The skull, although not measurable, was dolichocranic, being long, relatively narrow, and high vaulted. The forehead was high with slight development of the supraorbital ridges. The mid-face was characterized by prominent, steeply angled nasal bones, a moderately narrow nasal aperture, and large malar (cheek bones). The mastoid processes of the temporal bones were moderately large, and the nuchal ridge of the occipital was well-defined with a moderate-sized protuberance. Although the epiphyses were fully united, the bones had a youthful appearance with compact cancellous bone and open cranial sutures.
The bones of the individual were moderately large with pronounced development of the muscle attachment sites on the humeri, radii, and ulnae and somewhat less pronounced ridge development on the femora and tibiae. The right humerus is slightly larger than the left one, with greater development of the deltoid tuberosity and the lateral supracondylar ridge; the asymmetry suggests right-handedness. The in-situ length measurement of the left femur was approximately 51 cm, providing a Trotter and Gleser regression predicted stature of 6 ft. +/- 2.1 in. (Ousley and Jantz 1996). The shoulder breadth, measured in the ground as the biacromial width of the scapulae, was 36 cm.

Only two pathological conditions were noted in the skeleton. The superior orbital plates of the frontal bone show slight porosity characteristic of cribra orbitalia, an osteological response often associated with anemia. Second, the left patella was scored for slight arthritic lipping. There was no evidence of perimortem bone trauma. The cervical vertebrae were poorly preserved and could not be judged for trauma that likely would have resulted from hanging. The leg bones were better preserved but showed no fracturing that might have occurred from being struck by the dislodged platform rail.

With regard to possible antemortem injuries, the ribs were fragmented and deteriorated, and a healed rib fracture might not have been detected. The jaws and teeth were sufficiently preserved to rule out prior damage caused by an alleged gunshot wound.

The dentition showed normal occlusion with good alignment and no crowding. Not one of
the teeth was carious or abscessing, and there was only slight enamel crown wear. No enamel defects (hypoplastic lines) were present. The teeth were stained a light golden brown from using tobacco. No pipe facets were present.

**Associated Artifacts**

The coffin was widest at the elbow and was buried at a depth of 113 cm (44.5 in). The wood was identified as belonging to the Yellow pine group, which includes a variety of species that are microscopically identical (Alden 1997; Laurie Burgess 2001, pers. comm.). The lid was secured with five white metal coffin screws with ferrous alloy shafts. The screws have a slightly stepped base, with stippling present on the base; straight, undecorated sides; and a slightly domed top encircled by another band of stippling. Their crown diameters are 16.4 mm with a height of 8 mm. Aside from 77 cut nails and the screws used for construction, few personal artifacts were recovered, but these proved quite informative and are described below.

**Medal of the Immaculate Conception**

A thin, cast religious Miraculous Medal, measuring 2.2 cm long and 1.8 cm across with its suspension loop set parallel to the facial plane was found near the xiphoid process of the sternum. The Virgin Mary surrounded by text was on one side of the medallion. The face of this side has the image of the Virgin Mary in a long, flowing robe, hands at sides with palms open to the viewer. The head and shoulders are partially obscured by corrosion. The inscription that forms an arc surrounding the image is partially legible: “O Mary Conc(eived).Without Sin/Pray For Us Wh(o) (Have Recou)rse to You” (Association of the Miraculous Medal 2003). The opposite side of the medallion has symbols common to Catholic iconography (Figure 7) (Burgess 2001). A series of 12 stars with an M surmounted by a bar and a cross are above the hearts of Jesus and Mary, one crowned with thorns and the other pierced with a sword. The metal shows no corrosion typical for cupric alloy, and it is more likely a white metal alloy, or—due to the nature of the smooth, dark corrosion present—may be silver. The medal is dated 1830 in commemoration of the year that Catherine Labouré (subsequently canonized) experienced visions of the Virgin and established of the Order of the Sacred Heart.

The medal was suspended around the neck of the burial by a fabric cord. A small piece of rusted metal that appears to have been part of a necklace clasp, measuring 4 mm in diameter, was found with the cranial bones.

**Celluloid Fragments**

Three fragments of celluloid with an overall length of ca. 5.4 cm represent the tip end of a leaf (Figure 8). The yellow-green color and consistency are similar to other celluloid articles made in the late-19th century in the United States (Fox 1998). The leaf is likely part of the rosette or flower Longley was reported to have worn in his lapel at the time of his execution.

**Heels**

Two boot heels containing at least 10 layers of stacked leather secured by a row of square
metal nails around the perimeters of their bottoms were recovered. This method of fastening heels is typical of the 1880s time period (Fox 1984, 1998).

Also found were two cupric alloy shirt snaps from a long-sleeved shirt; a shanked shell button; a white, Prosser molded glass button with four holes set in a depressed center with characteristic stippling; and a badly deteriorated, gripper-type ferrous alloy button. White metal screws with slotted heads and stippling and the clothing artifacts are appropriate for an 1870s burial (Fox 1998; Burgess 2001).

Comparison of Mitochondrial DNA with a Longley Relative

An intact second molar was removed from the left maxilla of the cranium. A comparison of mitochondrial DNA (mtDNA) extracted from it and of a blood sample from Helen Chapman—whose great-grandmother was a sister of Longley’s—strongly supports identification of the remains as those of William Preston Longley.

When nuclear DNA is too minimal or degraded for successful analysis, mtDNA may often be extracted from aged skeletal remains (Holland and Parsons 1999; Melton and Sensabaugh 2000). Since mtDNA is inherited unchanged within a maternal lineage, any maternal relative of an individual can provide a reference sample for comparison. Genealogical records of Michael Alan Reese establish Helen Chapman’s relationship to Sara Ann Longley, Bill’s mother, through an unbroken female line that spans five generations.

After thorough cleaning, the tooth with its intact roots was powdered and 0.40 g was used in a silica/guanidinium thiocyanate DNA extraction protocol (Höss and Pääbo 1993). Since the first round of PCR amplification revealed that the mtDNA in the tooth was too degraded for the use of standard primer pairs, an ancient DNA approach was applied (Stone and Stoneking 1996). Four overlapping PCR amplification products, ranging in size from approximately 100 to 200 base pairs, were generated to recover partial sequence data for the first hypervariable region only (HV1; positions 16056–16409) of the control region of the mtDNA molecule.

The mtDNA profile of Helen Chapman’s blood yielded a complete type with the nucleotide sequence obtained for positions 15997–16400 (HV1) and for positions 30–407 (hypervariable region 2 [HV2]). The tooth analysis was carried out prior to the analysis of the known blood sample to eliminate the possibility of cross-contamination. Comparisons of the mtDNA sequences from the tooth and blood over all regions common to both samples indicated that the contributor of the tooth sample could not be excluded as a maternal relative of Helen Chapman because there was identity at each of 345 nucleotide positions.

A database search of more than 4,142 mtDNA sequences (the Scientific Working Group on DNA Analysis Methods database [Budowle et al. 1999]) was carried out to estimate the approximate size of the pool of potential contributors of this type of mtDNA (Table 1). The partial type common to the tooth and blood had...
previously been observed 18 times; however, the full type of Chapman, including both HV1 and HV2, had not previously been observed in this database. Within the database, 16 of the 18 sequences that matched the tooth and Chapman over just HV1 had a T to C nucleotide substitution at position 195 in HV2. Chapman does not have this substitution.

To determine if the tooth matched Chapman at position 195, an additional amplification of a short fragment capturing HV2 bases 173–284 was carried out for the tooth sample. Although the overall quality of the fragment’s data was less than optimal, it was also possible to confirm that the tooth sample did not have this substitution at position 195, thus upholding the match to Chapman. As a result of this additional information, the number of matches for the regions surveyed decreased from 18 to 2 in the current database of DNA sequences of North American forensic significance.

Mitochondrial DNA is not a unique identifier, as individuals sharing a maternal lineage will have the same mtDNA profile. It is therefore possible that an individual selected at random who does not share an apparent maternal relationship with Helen Chapman could have her mtDNA type. The odds of this occurring would be very low based on the relative rarity of her type in the current database.

### Conclusion

This project proved far more complicated than originally anticipated and required 15 years to resolve. Rumors of a staged death and questions about the true fate of Bill Longley arose immediately following the hanging and have continued with advocates to the present day. Initially, it was thought this mystery could be quickly answered by the simple excavation of a marked grave. Unfortunately, research revealed that the original marker, placed four decades after interment, had been moved several times and was ultimately stolen. The contemporary marker is not directly associated with a grave.

Extensive review of incomplete historic notes relating to these moves, consultation with “old-timers,” extensive probing and geophysical exploration of potential areas to locate unmarked graves, and field assessment of selected burials were undertaken. None of those remains fit the physical description of Longley in terms of age, sex, and race, and no coffins filled with stones instead of bones were uncovered. Determination of the true location depended upon successfully matching a problematic historic photograph of a well-defined burial mound with contemporary photographs taken at roughly the same place and at the correct angle. Establishing direct correspondence between landscape features

### TABLE 1

<table>
<thead>
<tr>
<th>Sample</th>
<th>Hypervariable Region 1</th>
<th>Hypervariable Region 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>16126</td>
<td>16163</td>
</tr>
<tr>
<td>Standard</td>
<td>T</td>
<td>A</td>
</tr>
<tr>
<td>Tooth</td>
<td>C</td>
<td>G</td>
</tr>
<tr>
<td>Chapman</td>
<td>C</td>
<td>G</td>
</tr>
</tbody>
</table>

(-) At this position the reference sequence (top line) has no base and a base observed in a comparison sample is an insertion.
(nd) This base was not determined for this position in this sample.

The table does not contain data reflecting the match at position 195, as this site was not substituted with respect to the Standard (top line). Source: Anderson et al. 1981.
and vintage markers, using advanced computer graphics, led to the excavation of an unmarked burial located several feet east and north of the contemporary marker. Field excavation identified remains seemingly consistent with Longley and a comprehensive osteological assessment was undertaken. Forensic anthropological analysis and genetic comparison with a Longley family descendant lead to the conclusion that William Preston Longley died on the gallows on 11 October 1878. Contemporary observations relating to his attire and burial are borne out by the archaeological evidence. Longley’s story that he had sustained a bullet injury to the face is discounted. Given the findings, one must conclude that the Texas lawmen got their man, and justice was served. Longley’s reinterment and final tribute, held on 19 July 2001, was attended by four generations of Longleys and other citizens of Giddings. His remains were taken to the cemetery in a horse-drawn antique hearse followed by a female mourner in period costume carrying a wildflower bouquet.

Acknowledgments

Professional assistance was provided by the University of Texas-Arlington (UTA), the University of Texas-San Antonio (UTSA), the National Museum of Natural History (NMNH), and Mitotyping Technologies, LLC (MT). Ted Wax of Gonzales, Louisiana, deserves special recognition for initiating this project, providing background information on Longley and the Giddings Cemetery, and persisting in his search for the facts. We are indebted to the Longley family, especially Janis Hannes and Michael Alan Reese for their support, and to Helen Chapman for the blood sample. Suzanne Ellwood contributed to all aspects of this investigation and helped locate the grave using computer graphics. The technical expertise of Gloria Dimick and Kimberlyn Nelson (MT) is acknowledged. Sandra Schlachtmeier (NMNH) helped craft this manuscript. Shelly Smith (UTA) compiled the field notes. The excavation was completed with the help of Dana Kollmann (NMNH), Jeff Francis, Tony Lyle, Mary DeWitt, and Christian Crowder (UTSA). Karin Bruwelheide and David Hunt (NMNH) helped with the osteological analysis. Chuck Pratt (UTA) provided information on camera technology and helped align and date the Rose Collection photograph. Laurie Burgess (NMNH) and Anne Fox (UTSA) identified the burial artifacts. Douglas W. Ellison provided historical information about Longley. This excavation was conducted under Antiquity Permit No. 1993 from the Texas Historical Commission. The Giddings City Council, Mayor Paul Kipp, Alfred Zoch of Phillips & Lucky Funeral Home, Texas State Archaeologist Pat Mercado-Allinger, the Lee County Historical Society, and Malcolm Richardson are gratefully acknowledged for their help. Partial funding was provided by the NMNH, UTA, Louisiana State University, Chedd-Angier Production, Co., and Ted Wax.

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Ground-Penetrating Radar Techniques to Discover and Map Historic Graves

ABSTRACT

Ground-penetrating radar is a geophysical technique that can be used to identify and map features commonly associated with historic graves, including intact or partially collapsed coffins and vertical shafts. Data are collected by moving radar antennas that transmit pulses of energy into the ground along parallel transects within grids, recording reflections of those pulses from significant discontinuities within the ground. Visual analysis of radar reflection profiles can be used to identify both coffins and the vertical shaft features commonly associated with human burials. Spatial analysis of the reflection amplitudes within a grid consisting of many profiles (when converted to depth using site-specific velocities) produces three-dimensional maps of these burial features. The identification and mapping of graves can identify remains for possible excavation and study, and the results can also be used for statistical and spatial analysis when integrated with historical records. If identified by these methods, previously unidentified graves can be preserved in areas threatened by construction or erosion.

Introduction

Locating, studying, and sometimes excavating historic period graves can produce a great deal of information about the past not otherwise available from archival documents or other data sources. If the goal is to study skeletal remains for osteological or molecular studies, the first step must be identification of the graves of interest. Many historic cemeteries are poorly maintained and often threatened by erosion, development, and agricultural operations, making the identification of graves important if they are to be preserved. Sometimes unmarked graves need to be identified so that human remains may be removed if threatened by construction or even to make way for additional burials when cemeteries expand their boundaries or fill in areas that appear to be vacant.

Geophysical techniques such as ground-penetrating radar (GPR) can be used to locate unmarked graves and recover other information about historic period cemeteries. GPR can often determine grave attributes such as depth of burial, grave size, type of caskets and their orientation; numbers of graves in certain locations; and the spatial distribution of graves within certain areas of a cemetery. This information can then be integrated with birth and death records, information found on headstones, or other historical documents to provide a database on the lives and behaviors of the individuals buried there. Often this information is not available by other means.

Some Euroamerican cemetery characteristics such as the depth, orientation, and spatial distribution of grave shafts have changed over time. Often they reflect the economic background, ethnicity, and religious, social, or aesthetic values of both the dead and those doing the burying (Farrell 1980). Although in some cases these characteristics are well documented (Crissman 1994; Sloan 1995) they have not generally been applied to the study of specific communities or integrated with historic records, especially in older cemeteries where grave markers are moved or missing. GPR has the potential to precisely map these graves and add an important data layer to any historical study involving burials and burial practices.

Lacking geophysical means, finding historic graves using traditional probing or excavation methods has often been a “hit or miss” task for most archaeologists. Attempts to locate these subsurface features using visual analysis of surface soils or vegetation changes are also fraught with problems. Head- and footstones that were once present in many historic cemeteries are often deteriorated, relocated, or missing. Written documentation about grave locations is often incomplete, inaccurate, or absent. Falling trees can uproot underlying sediments as well as human remains; animals can burrow into graves; and the wood associated with coffins and surface markers quickly rots with little or no trace. Often there is little to assist researchers in locating graves other than vague memories about where burials were located or poorly drawn sketch maps.

Archaeologists have attempted to locate graves by inserting probes in the ground in
an attempt to detect soil changes, voids, or areas that might be less compacted (Killam 1990). Some have resorted to dowsing, with little success (Barrett and Besterman 1968; Reese 1985; Van Leusen 1998) or employed psychics (Goodman 1977), and a few have even attempted to use dogs, purported to have acute senses of smell, that are trained to sniff out human remains (Killam 1990).

A more reliable method that has been used to locate and then map historic graves is the use of geophysical devices that can measure physical and chemical changes in the ground. These changes may be related to grave shafts, coffins, void spaces, and even the human remains themselves (Bevan 1991; Nobes 1999; Davenport 2001). The most common of these are magnetic gradiometry, electrical resistivity, GPR, and electromagnetic conductivity. Magnetic methods use passive devices that measure small changes in the Earth’s magnetic field that are influenced by changes in soils and buried materials below the surface. These changes can result from the presence or absence of metal in coffins or even minute differences in soil and sediment types that exist between grave shafts and undisturbed adjacent materials. The other three most commonly used geophysical methods use tools that transmit energy into the ground and then measure how that energy is affected by changes in the ground related to the presence or absence of graves, grave goods, and soil changes. The resistivity method transmits an electrical current into the ground and measures the differences in voltage between the transmitting device and a recording device some distance away. When mapped spatially, changes in these resistance readings can be related to the presence or absence of graves. A similar method of energy transmittal is used in electromagnetic (EM) conductivity, where an EM field is induced into the ground and measurements are taken, which indicate how that field is affected by the underlying deposits. GPR is also an active method that transmits pulses of radar energy of differing frequencies into the ground and measures properties of the reflections derived from buried materials in the ground.

All of these geophysical methods collect data along a series of transects within a grid, which can be interpreted individually as two-dimensional profiles or as a group to spatially map differences in ground conditions that might be related to the presence of graves. The differences in the readings within the grid, when mapped spatially, can often be related to burial phenomena, such as the presence or absence of artifacts associated with human remains or geological changes that can be related to grave shafts. The human remains themselves cannot generally be detected since there is not enough contrast between them and the surrounding material.

GPR is one of the best methods to map graves because it is capable of measuring both physical and chemical changes in the ground in three dimensions; therefore, depth as well as the spatial distribution of graves can be determined (Bevan 1991; Davis et al. 2000). This can be accomplished because radar pulses are transmitted from a surface antenna and reflected off buried discontinuities. The returning pulses are measured in elapsed travel time. When time is converted to distance (using measurable velocities common to each site), depth in the ground can be readily determined. In addition, radar energy is readily reflected from any discontinuity in the ground, including soil compaction changes, mineralogical differences, sediment size distinctions, void spaces, and the type and concentration of associated artifacts. Amplitudes of the reflected waves can also be precisely measured, indicating differences in material properties within the ground, producing an additional measurement that is valuable in locating subtle buried features.

GPR systems are compact and easily transported to and from the field. A typical system consists of a radar control system and associated computer, antennas, and a power source (Figure 1). Grids of data (up to 40 × 40 m) can be collected in a day, depending on the transect spacing and the number and complexity of surface obstructions. Reflection data are easily transferred from the GPR system to a laptop computer for immediate analysis, with preliminary results often available just hours after collection.

Grave Characteristics

Physical anthropologists have long concerned themselves with finding human remains, whether intentionally buried or covered and preserved by natural means. A large body of literature
addresses the detection of human remains for forensic purposes, both anthropological and criminal (Imaizumi 1974; Boddington et al. 1987; Killam 1990). Addressed here is the use of GPR techniques to detect and map inhumations that were deliberate burials, usually in cemeteries, and not those that might have been the result of flood events, drowning, or other natural actions.

Most historic period Euroamerican burials in North America are primary interments, with and without coffins, placed horizontally, without changes in position since burial. There are, of course, many other deliberate burial types that were common throughout the world as well as North America. For example, secondary interments occurred where bones were collected after decomposition of the soft flesh and then reburied or where many individuals were buried in one grave, including ossuaries and other mass graves of this sort. In these cases, human remains are rarely in an articulated anatomical position and associated grave goods can be jumbled and are difficult to detect geophysically. Multiple interments are also common in military battlefield contexts where several bodies might be located in one grave. These can also be quite complex. Only those more common singular graves where human remains were buried once and not reinterred or highly disturbed are discussed here.

Each such grave has four distinct physical features that can potentially be imaged using GPR techniques: (1) the natural soil or substrate below and surrounding the grave shaft, (2) the buried coffin or human body and its associated artifacts, (3) the backfill used to fill in the vertical shaft, and (4) the surface layers of sediment or soil that have accumulated on that shaft after interment. Of these four features, the contact between the shaft and the surrounding material, coffins containing remains, and sometimes associated artifacts are what can be readily imaged using GPR. When human bodies, coffins, urns, or any other grave goods are placed in the ground, a vertical shaft is excavated through surface soils and underlying sediment or rock units, producing an aerially distinct and often recognizable feature that can be seen in GPR reflection profiles. During excavation of a grave, the natural substrate and surface soils are almost always placed on the ground nearby and then returned to the grave shaft after interment. The excavated material that is used to backfill the shaft is highly altered during this process, becoming less compact and more homogenized, losing any natural stratigraphy that might have existed prior to digging. Backfill material will then settle over time, sometimes leaving a natural depression on the surface but also producing settling structures within the shaft that can be distinctive.

If graves are placed in horizontally layered material, the backfill material can be quite apparent as the natural stratigraphy is disturbed during digging, and the zone of truncation is readily visible in profile. The backfill material lacks any natural stratigraphy and the interface between it and the surrounding material can be readily identified in both excavation faces and GPR reflection profiles (Figure 2). In areas where weathered bedrock is shallow or the ground is composed of gravely or cobble-rich sediment, there can be a good deal of “clutter” in both the disturbed area of the grave shaft and the adjoining undisturbed material, making vertical definition of grave shafts much more difficult to discern. The same is true in homogeneous fine-grained soil and sediment that has little natural stratigraphy. In this case, little physical differentiation exists between shaft backfill and natural substrate.

In cases where individuals were placed in coffins or other containers, these will have deteriorated over time and partially or totally collapsed, producing subsurface and surface slump features. These surface depressions will often slowly fill in with sediment and soil will
form, leveling the ground surface and making surface identification of these graves difficult. More substantial caskets constructed of oak or metal can remain intact for a much longer time, producing a noticeable void space in the ground that is readily detectable with GPR. The same is true for burial vaults made of brick or stone, which often preserve void spaces surrounding human remains for centuries. Burials within buildings, such as under the floors of churches or in small family shrines and mausoleums, will also preserve coffins and associated remains for a very long time. The void spaces beneath building floors are often distinctly visible on GPR profiles.

The range of primary interment characteristics, soil and sediment differences, climate and soil chemistry factors, and many other variables often make challenging the detection and mapping of graves using GPR. Usually GPR will detect at least the contact between the vertical shaft backfill and the substrate and also the void spaces in completely or partially intact coffins. If there has been a good deal of postinterment disturbance of burials due to human or animal and plant disturbance, normal grave features can be highly altered, making detection challenging by any method, including geophysics.

**GPR Method**

GPR data are acquired by transmitting pulses of radar energy into the ground from a surface antenna and reflecting that energy off buried objects, features, or bedding contacts. At a paired receiving antenna the elapsed time from when pulses are sent and then received back at the surface as well as the strength of that energy are measured and recorded. When collecting radar reflection data, surface radar antennas are moved along the ground in transects within a surveyed grid, and a large number of subsurface reflections, called traces, are collected along each line. Often GPR recording systems can be programmed to collect at a density of one trace, or even more, every 5 cm along the surface transects. When reflection traces are stacked together along one transect line, a reflection profile is created that illustrates a cross-section of the ground much like what might be visible in a trench wall (Figure 3).

As radar energy moves through various materials in the ground, the velocity of the propagating waves will change depending on the physical and chemical properties of the material through

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**FIGURE 2.** A primary interment with distinct vertical shaft walls incising through naturally layered soil and sediment layers. (Photo by author.)

**FIGURE 3.** Reflection profile from a cemetery with wooden coffins interred between 1898 and 1921. One metal coffin is identifiable by the alternating strong reflections below it. (Drawing by author.)
which they are traveling (Conyers 2004:26). At each velocity change a portion of the propagating wave will be reflected back to the surface to be detected at a receiving antenna that is usually paired with the transmitting antenna. The remaining energy will continue into the ground until it is absorbed and dissipated. The greater the contrast in electrical (and to some extent magnetic) properties between any two buried materials at an interface, the stronger the reflected waves will be that travel back to the surface, and the greater the amplitude of recorded signals (Conyers 2004:49).

**History of Ground-Penetrating Radar**

Radar devices that transmit energy into the ground, as opposed to searching for objects in the air, were first experimented with in the 1920s to determine the depth of ice in glaciers (Stern 1929). The ground-penetrating aspects of radar technology were then largely forgotten until the late 1950s when U.S. Air Force radar technicians on board airplanes noticed that their radar pulses, used to determine altitude, were penetrating glacial ice when flying over Greenland. A number of mishaps occurred because airborne radar analysts detected the bedrock surface below the overlying ice and interpreted the bedrock instead of the ice as the ground surface, resulting in crashes. In 1967, the first prototype GPR system (similar to those used today) was built by NASA and sent on a mission to the moon in an attempt to determine surface conditions prior to landing a manned vehicle (Simmons et al. 1972).

One of the first archaeological applications of GPR was conducted at Chaco Canyon, New Mexico, in an attempt to locate buried walls at depths of up to one meter (Vickers et al. 1976). A number of experimental traverses were made, and the resulting reflection profiles were analyzed in the field. It was determined that some of the anomalous radar reflections represented the location of buried walls. These early studies at Chaco Canyon were followed by a number of GPR applications in historical archaeology that successfully located buried building walls and underground storage cellars (Bevan and Kenyon 1975). In these early studies what were described as radar “echoes” and “reverberations” were recognized as having been generated from the tops of buried walls. Depth estimates were made, using approximate velocity measurements obtained from local soil characteristics.

These initial successes were followed by other GPR studies in the 1970s and 1980s that also successfully delineated buried walls, floors, house platforms, and other buried archaeological features. Most initial successes were primarily a function of the very dry matrix material surrounding those buried archaeological features that was almost “transparent” to radar energy propagation, allowing for deep energy penetration and producing relatively uncomplicated reflection records that were easy to interpret.

Throughout the late 1980s and early 1990s GPR continued to be used successfully in a number of archaeological contexts, mostly as what could be called “anomaly hunting” exercises. Unprocessed or partially processed GPR reflection profiles were viewed as paper records or on a computer screen as they were acquired. Interesting anomalous reflections, which could possibly have archaeological meaning, were then excavated. This type of acquisition and interpretation method led to mixed results, with some successes and notable failures, often leaving many archaeologists with the impression that GPR was a “hit or miss” method at best. In the early 1990s GPR manufacturers began to market systems that could collect reflection data as digital files, thereby storing large amounts of reflection data for later processing and analysis. About this same time, inexpensive and increasingly powerful personal computers were also becoming available that could process these digital data in ways that had not been previously possible.

Recently, the application of two-dimensional computer simulation and three-dimensional processing techniques have shown that even radar data that does not yield immediately visible reflections when viewed in the field can still contain valuable reflection data when computer processed (Goodman 1994; Goodman et al. 1995; Conyers 2004:138). Computer enhancement of raw GPR reflection data and three-dimensional visualization of buried sites is now becoming widespread as researchers increase their familiarity with some of the recent GPR computer-processing techniques (Conyers et al. 2002; Conyers 2004:150).

GPR has not commonly been used to map graves, as they are not usually aerially
extensive, can be quite subtle features, and their characteristics vary greatly from site to site. Some notable exceptions are the historic cemeteries mapped by Bruce Bevan (1991) in the eastern and middle United States and those in permafrost in Norway (Davis et al. 2000). Somewhat less successful but nonetheless encouraging results were recently obtained at Texas and Hawaii military cemeteries (Buck 2003) and Maori burial grounds in New Zealand (Nobes 1999).

The success of GPR surveys in historical archaeology is largely dependent on soil and sediment mineralogy, clay content, ground moisture, depth of burial and surface topography, and the type of surface soils present. Electrically conductive or highly magnetic materials will quickly absorb radar energy and prevent its transmission into the ground. The best conditions for energy propagation are therefore dry sediments and soil, especially those without an abundance of clay, which can sometimes be very conductive.

The depth to which radar energy can penetrate the subsurface and the amount of resolution that can be expected in the subsurface are partially controlled by the frequency (and therefore the wavelength) of the radar energy transmitted (Conyers 2004:42). Standard GPR antennas propagate radar energy that varies in frequency from about 10 MHz to 1,000 MHz. Low frequency antennas (10–120 MHz) generate long wavelength radar energy that can penetrate up to 50 m into the ground in certain conditions but are capable of resolving only very large buried features. In contrast, the maximum depth of penetration of a 900 MHz antenna is about 1 m or less in typical materials. Its reflected waves are much shorter and can potentially resolve features with a maximum dimension of a few tens of centimeters. A tradeoff exists between depth of penetration and subsurface resolution. Most GPR surveys used to detect and map historic graves use antennas that range in frequency between 900 and 300 MHz, which produces good resolution data at depths between about 1 m and 3 m, respectively.

Data Collection and Data Analysis

To collect GPR reflections, paired antennas that generate the propagating radar waves and then record the resulting reflections are moved along the ground surface in transects, usually at a minimum of 10 m in length, with a transect spacing of 50 cm or less. Often a survey wheel is attached to the antennas, which will automatically record the horizontal location for all reflections that are recorded along each transect. Reflections that are received back at the surface from buried interfaces are usually recorded along many transects within a grid so that adequate spatial differentiation exists between burial features and natural soil and sediment substrate. Most stratigraphic layers, void spaces, and interfaces between coffins and backfill material, all of which are common to most historic graves, will reflect radar energy back to the surface.

The most efficient GPR collection method is to establish a grid across a survey area with reflection profile transects spaced between 25 cm and 1 m apart, depending on the subsurface resolution needed, the amount of ground to be covered, and the time budgeted for the survey. In GPR collection the elapsed time between pulse transmission, its reflection from interfaces in the ground, and subsequent recording at the receiving antenna is measured for each reflection in each trace as well as the reflected wave’s amplitude. The received reflections are then amplified, processed, and digitally recorded for immediate viewing on a computer screen and saved on some kind of storage medium for later postacquisition processing and display.

Distinct and often continuous horizontal reflections visible in reflection profiles are usually generated at a subsurface boundary such as a soil unit, stratigraphic layer, bedrock, or sometimes the water table (Figure 3). Reflections recorded later in time are those received from deeper in the ground. Hyperbolic shaped point-source reflections are generated from distinct point features in the subsurface, which in cemeteries are usually casket tops or sides and void spaces within intact or partially collapsed caskets. Similar hyperbolic reflections can also be produced by buried stones, tree roots, or tunnels created by burrowing animals, creating anomalous reflections that can often be confused with those of caskets. Point-source reflection hyperbolas occur because GPR antennas generate a transmitted radar beam that propagates from the surface into the ground in a conical
pattern, radiating outward as it travels deeper in the ground (Conyers 2004:57). Some radar energy will be reflected from buried objects that are not directly below the antenna. Only when the antennas are directly on top of the buried object will the radar reflections record the exact location and depth of the object. Reflection hyperbolas that are visible in reflection profiles (Figure 3) are generated because energy will be recorded from a buried point source prior to the antenna being directly on top of it, and antennas will continue to “see” the objects after they have passed. In the resulting hyperbola, only the apex denotes the actual location of the buried source. The arms of the hyperbola denote the reflected energy that traveled the oblique wave paths to and from the buried point source.

Metal- or lead-lined caskets produce both hyperbolic reflections and a series of distinct stacked reflections below the apex of the hyperbolas (Figure 3). This occurs because metal is a perfect radar energy reflector and almost all radar energy is reflected back to the surface from metal objects, which will then return back into the ground from the soil-air interface, only to be reflected back again, often many times along these same pathways. This creates a series of stacked high-amplitude reflections, indicative of a significant amount of buried metal in the ground. Narrower hyperbolas lacking in multiple reflections below their apexes are usually wooden caskets or the remaining void spaces from collapsed caskets. Smaller hyperbolas are often generated from smaller caskets, such as those of child burials. In some cemeteries without caskets or with deteriorated wooden caskets, little remains from the primary interment to reflect radar energy back to the surface, and no distinctive hyperbolas will be generated. Bones or small amounts of metal from grave goods may still be present, but they are usually either too small or do not contrast enough either physically or chemically from the surrounding matrix to produce significant radar reflections. In these cases only the contact between vertical grave shaft and the natural substrate will be visible in reflection profiles as distinct truncation of the undisturbed adjoining material (Figure 4). Sometimes a near-surface slump of soil into the grave shaft can be discernible in reflection profiles.

Three-dimensional images are very useful in the analysis of historic cemeteries, which can be readily constructed from GPR reflection data when many profiles are collected in a grid. This mapping technique is accomplished by producing amplitude slice maps at defined horizontal layers within a grid of reflection data (Conyers 2004:148). When abundant data are recorded along closely spaced transects in a grid and when good depth penetration of energy is obtained, a three-dimensional “cube” of reflections can be computer analyzed. The mapping of radar amplitudes is important because the degree of reflection, when mapped spatially, can show the distribution of physical and chemical differences in the ground that often are the product of buried grave goods and human remains. High-amplitude reflections often indicate substantial differences in coffin types, such as those composed partially or wholly of metal. Lower amplitudes can denote the location of wooden caskets. The amplitude slice-map method is usually more precise and less time consuming than attempting to visually identify many reflections of importance in each reflection profile in a grid, as there can often be tens or even hundreds of potentially important reflections. Computer processing of these reflect-
Amplitude slice maps are computer generated by comparing and spatially mapping all reflected wave amplitudes at defined depths in all profiles within a grid. Digital values of reflection amplitudes at each location in each profile are compared to those in adjacent profiles and then spatially interpreted, gridded, and mapped throughout a grid. The complete GPR database is then sliced horizontally in layers of any desired thickness and displayed to show the variation in reflection amplitudes at a sequence of depths in the ground. This produces images analogous to maps that might be constructed (but never would be, as it would be too time consuming) of all physical and chemical changes in arbitrary excavation levels within a very large standard excavation. The final product is a series of maps of certain layers in the ground, each of which illustrates the spatial distribution of both high- and low-amplitude reflections produced by caskets or other burial goods as well as other natural features (Figure 5). It is always interesting to compare maps of this sort to the location of existing headstones, especially in older cemeteries. In many cases the headstones have been moved over the years due to vandalism, natural processes, or other human-directed elements. The location of the GPR-mapped graves often correlates well with more recent graves, but sometimes there is little correlation with older graves as surface markers have been moved from their original locations (Owsley et al., this volume). It is also common to see distinct burials in portions of historic cemeteries where there are no markers or other documentation of graves at all (Figure 5).

Actual depth in the ground for each amplitude time slice is determined by estimating the velocity of the radar energy in the specific soil and sediment types present at each site. This velocity can be highly variable from site to site and sometimes even vary within a GPR grid. It is affected by numerous physical and chemical variables of the ground and by compaction and moisture content. These velocities can be estimated using computer programs that “fit” the geometry of point-source hyperbolas to a known mathematical formula known for radar wave travel in certain media, which is a very accurate way to determine velocity (Conyers and Lucius 1996; Conyers 2004:99). Other, more sophisticated methods can be used if there are open excavations available or the actual depth to caskets is known and where both radar travel time and distance to known objects can be measured in the field. Time slices should always be converted to depth slices for archaeological interpretation, regardless of how velocity is determined.

Conclusion

If soil conditions are conducive to radar penetration and reflections from within the ground are obtained along many closely spaced transects within a grid, a number of grave features can be detected using GPR methods. The two distinct grave features commonly visible are reflection hyperbolas from caskets and vertical
shaft truncation planes. Other features common in cemeteries such as large rocks, tree roots, or animal burrows may be confused with caskets, and care must be taken to differentiate them, usually by mapping all reflections spatially. Caskets will always produce spatially distinct reflection anomalies in the size of a human body, whether an adult or infant. Tree roots and burrows can be differentiated from human burials as they will produce elongated and sinuously shaped reflections. Individual rocks will almost always be visible in only one reflection profile and not on the parallel profiles, unless they are very large. The spatial distribution of these materials in the ground can be determined using amplitude slice maps and studied in real depth if the velocity of radar energy in the ground is obtained.

The other distinct grave elements that are visible in GPR data are the vertical planar surfaces of grave shafts that truncate surrounding sediment or soil layers. Often these features are the only clue to the location of graves if bodies were not placed in caskets or if caskets have subsequently collapsed and deteriorated. These types of features are less easily mapped using amplitude analysis and usually must be visually identified in reflection profiles and manually plotted on maps. Truncation surfaces are also only visible in reflection profiles if the undisturbed materials in the ground are stratified. A third, much less common, feature that is sometimes visible in reflection profiles consists of settling features in surface soils that can occur when grave backfill material compacts over time, allowing surface soils to become depressed. These features are sometimes visible in reflection profiles but, by themselves, would not be indicative of grave locations, as there can be other origins such as animal burrow collapse and the disintegration of rotting tree roots.

The use of GPR as a grave-mapping tool can be a precursor to both invasive and noninvasive archaeological studies. Finding human remains that might be excavated for biological research or the analysis of grave goods is one very direct outcome of GPR mapping. Other types of studies not commonly used to date in archaeology would be the incorporation of GPR maps and information with historical records. This could potentially yield important information about changing burial practices over time and differences in ethnicity or economic background of the deceased, their survivors, and the communities in which the burials were located. The efficiency and accuracy of GPR techniques for historic cemetery mapping is just being realized and has the potential to add much to any historical study, whether it involves excavation of remains or noninvasive mapping of the graves alone.

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Skeletal Remains from the Confederate Naval Sailor and Marines’ Cemetery, Charleston, SC

ABSTRACT

The 1999 burial recovery project at the Confederate Naval Sailor and Marines’ Cemetery (38CH1648), Charleston, South Carolina, provided a rare opportunity for the skeletal analysis of Civil War period remains. Dating from 1861, the cemetery contained the remains of 40 males of European ancestry who are known to have died in southeastern naval hospitals. Five of the men buried at the site are believed to have been the first crew of the H.L. Hunley submarine. In conjunction with historical and archaeological evidence, the presence of skeletal and dental lesions is used to draw conclusions regarding the backgrounds, health and disease experiences, military ranks, and occupational stresses experienced by the naval and marine personnel buried at the site.

Introduction

The Confederate Naval Sailor and Marines’ Cemetery, originally known as the Sailor’s Home Cemetery, was established in 1861 on what was the eastern shore of the Ashley River in Charleston, South Carolina. The area also contained a widows’ and dependent orphans’ cemetery and public burial grounds. According to records, the property was ceded to the Confederate States government at the beginning of the Civil War for use as a cemetery. The property is now covered by the Citadel’s Johnson-Hagood Stadium at present-day Fishburne and Hagood streets. The stadium was constructed on the property in 1947 with the prior agreement that the graves would be moved. City of Charleston Regular Meeting records refer to the intent to “employ the services of a mortician” for the purpose of removing the gravestones and the graves to a “piece of land directly west [of the cemetery]” (McAlister 1947:613). Whether due to fraud or accident, the gravestones were lost and the graves were never moved.

The 1993 restoration of Charleston’s Magnolia Cemetery, approximately two miles north of Johnson-Hagood Stadium, following Hurricane Hugo revealed the fact that some of the gravestones from the adjacent widows’ and dependent orphans’ cemetery had been moved there. The only item from the naval cemetery that had been moved was a monument, erected in 1922 by the Ladies’ Auxiliary, a local benevolent society. The realization that the remains of 40 Confederate sailors and marines probably still lay buried beneath the parking lot and stadium area at Johnson-Hagood generated great public interest and was the impetus for an archaeological and historical analysis and recovery (Leader and Burbage 2000:1). Two multiorganizational burial recovery efforts took place in 1993 and 1999, in which 39 Confederate burials were exhumed, relocated, and reburied in the military section of Magnolia Cemetery. Thirteen of these burials were excavated during the 1993 project. These remains were not analyzed. Twenty-six burials were recovered during the 1999 project. A period of time during fall 1999 was allotted for the analysis of these remains prior to their reinterment. A 40th burial, which was too poorly preserved for analysis, was excavated in spring 2000.

Due to the rare opportunity to examine Civil War-era skeletal remains within strict time constraints, the skeletal analysis was conducted as a means of gathering as much information as possible for potential use in multidisciplinary research. The goal of the skeletal analysis of the remains from the Confederate Naval Cemetery was to obtain data to address the demographic makeup of the sample; indications of the health, disease, and nutritional status of the group; evidence of the stresses associated with naval and marine occupations; possible evidence of selective recruiting based on physical characteristics within the Confederate Navy; and possible military rank and socioeconomic differences within the sample. The rumored Irish origin of many of the sailors was of particular interest due to the potential of finding skeletal evidence of the health consequences of the great Irish famines of the era.
Cemetery History

Limited documentary reference, the names recorded on the Ladies’ Auxiliary monument, and circumstantial evidence provide all that is known about the sailors and marines interred at the cemetery. Undated news clippings from the files of Augustine Smythe, a Confederate sailor, indicate that one of the Hunley’s crewmembers, John Kelly, was an Irish immigrant (Smythe 1890). The surnames of most of the sailors and the local lore of Charleston also point to Irish origins. These are likely to have been men from lower socioeconomic groups, probably with prior sailing experience. The lack of experienced pilots and navigators was a serious hindrance to the Confederate Navy and forced the southern states, in many cases, to employ civilians and foreigners as navigators, junior officers, and seamen (Luraghi 1996:25; Laxton 1997:27). Southern ports, including Charleston and Savannah, played significant roles in the reception of Irish immigrant ships (Laxton 1997:27). Additional historic sources refer to the participation of thousands of Irish immigrants in the American Civil War (Miller 1999:180).

It is also likely, based on archaeological evidence, that some of the men buried at the naval cemetery were officers and midshipmen, probably from middle- to upper-class backgrounds. The majority of Confederate Naval officers were either former U.S. Navy officers of southern birth or experienced civilian sailors (Mark Ragan 2000, pers. comm.). Associated naval buttons revealed that one of the individuals at the cemetery (Burial 15) was buried in a naval officer’s uniform.

The names and information inscribed on the Ladies’ Auxiliary monument indicate that the majority of the sailors died in naval hospitals in Georgia, North Carolina, and Florida. Archaeological evidence found with the burials, such as white glass buttons possibly from hospital garments, is consistent with the recorded information. In addition, the monument’s inscriptions, derived from the Confederate war record, document the burial of the “Torpedo Boat Men” or presumed first crew of the H.L. Hunley at the cemetery.

The hand-powered H.L. Hunley submarine, completed in 1863 by machinists James McClintock and Baxter Watson with the support of Horace L. Hunley of New Orleans and British machinist William Alexander, carried a crew of eight and was designed to destroy enemy ships through the use of an explosive, harpoon-mounted torpedo device. The 40 ft. craft appeared to work well in practice and succeeded in destroying several targets in mock attacks (Schafer 1996:116–117; Ragan 1999:40).

After completion of testing, General P.G.T. Beauregard ordered the submarine to be sent from Mobile to Charleston, hoping it would be useful in breaking the blockade of federal ships at Charleston Harbor (Schafer 1996:117). On 30 August 1863, the craft was prepared to go into action against the U.S.S. New Ironsides. This marked the first in a series of fatal sinkings. In what was described as an “unfortunate accident,” the moorings of the boat, then known as the “Whitney Submarine,” became entangled with those of the steamer C.S.S. Etowah. The submarine, whose hatches were still open, went to the bottom of Charleston Harbor near old Fort Johnson, taking five crewmembers down with it (Schafer 1996:118). Four of the accident victims are listed as Frank Doyle, John Kelly, Michael Cane, and Nicholas Davis of the Confederate gunboat Chicora. The fifth drowned man is thought to have been Absolum Williams, a crewmember of the C.S.S. Palmetto State (Ragan 1999:70).

On 14 September 1863 the submarine was successfully brought up with the aid of two divers. Historians suspect that removal of the bodies through the submarine’s small hatches following almost two weeks underwater probably required some form of dismemberment (Ragan 1999:58). Following cleaning and repair of the boat, Horace Hunley traveled to Charleston to offer his assistance in preparing the craft for its next mission. The boat soon became known as the “H.L. Hunley torpedo boat” (Schafer 1996:119).

The following Confederate invoice from 1863 documents the transport of the bodies of the submarine crew to the cemetery and their burial in unusually large or oversized wooden coffins:

Confederate Navy Department. Charleston, September 22, 1863. (pay) To: Joseph Poulnot $135.00 for: 5 Coffins at $15.00 (each) $75.00, Transportation to Mariners Graveyard $20.00, Interment of 5 seamen from the torpedo boat $6 (each) $30.00, Drayage of coffins...
to R.R. Wharf $10.00. I certify that the above is correct, the amount is large but the body(ies) had been a long time under water and required larger coffins. John A. Payne, Lieut. C.S. Navy (Ragan 1999:82)

**Mortuary Context**

The 1999 burial relocation project was directed by co-principal investigators Jonthan Leader of the South Carolina Institute of Archaeology and Anthropology and Randy Burbage of the Confederate Heritage Trust of Charleston. Fieldwork (Figure 1) took place from 21 June to 18 July 1999. Due to lack of local availability, no physical anthropologists were involved in the exhumation process. Skeletal analysis of the 26 burials recovered in the 1999 project was undertaken by the primary author with the permission of Jonathan Leader and the Confederate Heritage Trust. Due to poor preservation, only 22 of the 26 recovered individuals could be analyzed. Preservation at the site ranged from complete, intact skeletons (Figure 2) to eroded and pulverized bone material. Factors including soil acidity, construction of the stadium, drainage, and heavy pedestrian traffic likely contributed to this wide variation in preservation. Depth of the graves ranged from 3 in. to 6 ft. below the surface.

Evidence supporting the identity of the *Hunley* crew burials within the cemetery is circumstantial but convincing. Burials 17, 17b, 30, and 30b were buried two to a shaft (superimposed) in oversized, simple, carpenter-built coffins as opposed to the manufactured or store-purchased models of the era. These coffins measured as broad as 30 in. (Burial 17) compared with the other coffins that ranged in width from 14 to 25 in. This stacking seems highly unusual in a military cemetery of the era, considering that the plot was nowhere near full and may represent an attempt at secrecy or concealment of the number of casualties.

Five men are known to have died in the submarine accident and based on an oversized carpenter-built coffin, Burial 13 is thought to be the missing fifth crewmember. In addition, Burials 17 and 17b appear to have been buried in a disarticulated manner based on the position of individual bones in the ground. Burial 17’s poorly preserved cranium was found at waist level on the skeleton and its left arm and right leg appeared to have been detached from the body. The left arm, clavicle, scapula, and cranium appeared to be disarticulated from the...
rest of the body of Burial 17b based on their locations in the grave. Burial 30’s forearms and feet were absent. This is consistent with Ragan’s theory that the decomposing bodies were probably dismembered in order to remove them from the submarine hatches after having been submerged for two weeks (Ragan 1995:58). Tzippy Kahana and colleagues (1999) describe “bloating, marbling, and [skin] slippage” among cadavers recovered from a shipwreck following 25 days immersion in seawater of 10º–12º C. The average water temperature of Charleston Harbor in August is significantly warmer (28º C), and bloating and putrefactive changes would probably have been quite advanced following 14 days of immersion (National Oceanographic Data Center 2004).

Although the context of Burials 17 and 17b was apparent in the soil, the skeletal material was highly fragmentary and did not remain intact through excavation and cleaning. It is unfortunate that these burials were so poorly preserved, as they might have displayed evidence of dismemberment in the form of saw or cut marks. Burial 13 was represented by little more than tooth crowns and soil stains. Burials 30 and 30b were fairly well preserved but did not display any identifiable evidence of cut, saw, or chop marks. It should be noted that both of these burials were missing their hands and distal portions of the radius and ulna of both forearms. No hands were recovered in the graves. Due to deterioration of the cut or broken ends of these bones, it was impossible to determine how they had been disarticulated. An additional possible explanation for the disarticulation of limbs is that the bodies came apart during attempts to extract them from the machinery and confined spaces of the vessel.

The association of archaeological evidence in the form of coffin types, coffin hardware, and officer’s uniform buttons with the presence of gold-foil fillings and other forms of dental restoration is suggestive of rank and socioeconomic differences within the sample. Two of the 19 individuals in the naval sample with observable dentitions (Burials 18 and 34) displayed evidence of dental restoration. Both had gold-foil restorations of the anterior and some posterior teeth (Figure 3). Several of the larger lesions were filled with nongold, possibly tinfoil or amalgam restorations. Considering the historically documented high price of dental restoration, especially in the southern states during the Civil War, inferences of higher socioeconomic status or wealth may be drawn from the extensive dental work present in these individuals.

In addition to their dental restorations, Burials 18 and 34 were buried in expensive, store-purchased coffins. Among the analyzed portion of the naval sample, five of the identifiable coffins were of this type. These caskets were similar to the typical manufactured catalog models of the period, constructed with hinges and locks. The other 13 were less expensive, carpenter-built coffins. These were “peg foot” coffins of the simplest possible construction, consisting of wooden planks and nails. Figure 4 depicts the exposed coffin of Burial 26, a simple box of this type. Evidence of higher socioeconomic

![FIGURE 3. Burial 34, gold foil restorations of anterior maxillary teeth and molar. (Photo by William D. Stevens.)](image)

![FIGURE 4. Burial 26, exposed coffin of simple construction. (Photo by Jonathan Leader, courtesy of SCIAA.)](image)
status may indicate that these men were of higher naval rank than the majority of men buried in the cemetery. The older age of these two individuals is additionally supportive of possible higher rank. Burial 15, the only identified officer among the group (based on officer’s uniform buttons) was buried in an expensive, store-purchased coffin with “keys” and a glass port. Unfortunately, poor preservation prevented the skeletal analysis of this individual.

These indications of status differences may also be partly associated with age at death, as those of lesser rank and financial means may have been the younger members of the group. The mean estimated age of the store-purchased coffin group (n=5) was 33 years, compared with 24.17 years for the carpenter-built coffin group (n=12).

Health, Disease, and Activity Patterns in the Confederate Navy

Historical sources provide abundant evidence of the impact of disease during the Civil War, especially in the coastal areas of the South. R. Thomas Campbell (1998:114) cites widespread illness as the primary factor in the deterioration of morale among the midshipmen stationed near Richmond, Virginia. Poor food and unhealthy living conditions led to sickness that left the Confederate warships shorthanded, especially in the winter months. According to naval records, large numbers of ironclad crewmembers were considered “too ill to perform their duties” at any given time (Campbell 1998:114). Campbell writes that seasonal changes brought on high rates of chills and fevers. The stifling, hot conditions aboard the steam-powered ironclads as well as exposure stemming from the lack of adequate cover or awnings on the decks of vessels were causes for significant deterioration in the health of the navy. Problems stemming from the inadequacy and poor condition of food sources included chronic dysentery and scurvy among the midshipmen. In response to these health hazards, the Navy Board of Surgeons recommended that the hatches of vessels be left open for ventilation, encouraged the scheduling of regular onshore exercise times, and ordered immediate increases in the supply of fruits and vegetables (Campbell 1998:115).

Civil War period accounts also detail the intense, physically demanding nature of naval duty at the time. Wartime manpower shortages frequently dictated that naval midshipmen were ordered into shore battery service on the besieged southern coastlines (Campbell 1998: 94–95). Historical sources provide descriptions of these coastal fortifications from which the obvious difficulty and physical strain associated with their operation can be inferred. Shore Battery Semmes in Virginia consisted of seven heavy guns mounted in large pits on the side of a small hill. Underground bunkers or “bomb-proofs” were located between the guns for the protected storage of ammunition. Most of the large guns at batteries like Semmes were mounted on naval carriages and operated with block and tackle systems identical to those of large shipboard guns. Period accounts indicate that it was not uncommon for the huge guns to be knocked off their carriages by well-placed projectiles from the opposing Union batteries (Campbell 1998:118).

Active service for the naval midshipmen also involved frequent scouting missions, usually by rowboat, and stealthy nighttime assaults on anchored Union vessels. Both sailors and marines participated in these missions, which often involved boarding enemy vessels and subsequent close-range and hand-to-hand combat (Campbell 1998:80–81,95). When the daily schedule provided relief from these onshore and nearshore operations, midshipmen faced equally demanding physical work aboard warships. Onboard training and the upkeep and maintenance of the large vessels were constant necessities (Campbell 1998:114).

Research Questions

Although undertaken as a “data salvage” operation, the skeletal analysis of the naval cemetery sample focused on several research questions. If, as proposed by historical researchers, the sample is largely comprised of recent Irish immigrants, many may have left Ireland in the 1840s—a period of widespread emigration due to the Potato Famine. Failure of the potato economy led to a “deterioration of the physical well-being of the Irish people” and was a major impetus for emigration to North America
(Laxton 1997:1; Harris 1999:4; Miller 1999:189). Ruth-Ann Harris (1999:2) describes eight episodes of major 19th-century Irish famine in the years prior to 1845 alone. It follows that the sample should display frequent evidence of the nonspecific skeletal signs of stress associated with conditions such as chronic malnutrition and disease during development. Additionally, signs of chronic disease and infection during adulthood should be present. The climate and disease environment of the South Carolina coast, as previously described, was extremely harsh.

Additionally important questions surrounded the occupational experiences of the naval sample. If, as research suggested, the sample is comprised of experienced former civilian sailors, skeletal indicators of the physical stresses associated with this demanding occupation should be present. Extensive occupation-related pathology is documented within another naval skeletal sample: the crew of the 16th-century British warship Mary Rose (Stirland 1988).

Further areas of inquiry centered on the possibility of evidence of selective recruiting for physical characteristics such as height. Recruitment standards favoring taller men have been cited as explanatory factors for disproportionately tall military samples (Steegman 1985:78). The question of whether individuals of different naval rank, as evidenced by archaeological evidence such as officer’s uniform buttons, might have corresponding differences in health and disease experience was also addressed.

Skeletal Analysis Methods

The skeletal remains were received on 8 September 1999 from Leader within heavy cardboard containers. Excavation records and site maps were included. In most cases, individual skeletal elements were packaged separately in aluminum foil within the boxes. Due to poor preservation, many of the burials were excavated in block form by major skeletal element. Each burial was individually washed and screened through 1/8-in. mesh. The skeletal remains were inventoried according to the forensic inventory form and protocols developed by Peer Moore-Jansen, Stephen Ousley, and Richard Jantz (1994). Following inventory, all skeletons were photographed using 35mm color print film.

Due to the wide variation in preservation at the naval cemetery, appropriate age determination methods were selected according to the condition of each set of remains. Morphological and metric methods were used to determine sex and ancestry within the sample. Stature was estimated using the stature estimation formulae developed by Mildred Trotter (1970:77–78). All evidence of skeletal and dental pathology within the sample was recorded by location and photographed. All observable skeletal elements were examined visually for abnormalities of shape, size, evidence of bone loss, abnormal bone formation, fracture and dislocation, cribra orbitalia and porotic hyperostosis, vertebral pathology, arthritis, and other pathologies as recommended in the protocols established by Jane Buikstra and Douglas Ubelaker (1994). All adequately preserved skeletal elements within the sample were measured according to the protocols published by Moore-Jansen et al. (1994). The standard forensic measurements form, including cranial and postcranial measurements, was used, and elements were measured using an osteometric board, sliding calipers, and hinged calipers. The data is curated in a master’s thesis at the University of South Carolina Department of Anthropology, Columbia, South Carolina (Stevens 2000).

Biological Profile

The general profile of the sailors and marines at the naval cemetery is of a male of Euroamerican ancestry in his late teens to late 30s of tall stature for the time period, with fair to poor dental health, considerable experience of illness during childhood, possible recent recovery from infection, and physical changes stemming from a demanding and stressful occupation. A notable exception to this profile is Burial 17b, one of the presumed Hunley crew members. This individual’s age at death is estimated at 8 to 11 years based on dental development. Unfortunately, the skeleton was too poorly preserved to permit analysis. Burial 17b’s apparent youth is a subject of continuing historical research focusing on the makeup of the submarine’s crew. The absence of evidence of traumatic injury is consistent with the documentary and archaeological evidence suggesting that most of these men died of
acute illness in naval hospitals. It should be cautioned that poor preservation within the sample may have obliterated any evidence of traumatic injury.

**Skeletal Pathology**

Skeletal evidence of traumatic injury was almost nonexistent among the naval cemetery sample. Only one incidence of traumatic injury was observed among the group: a healed depressed skull fracture of the frontal bone of Burial 26.

Periosteal reaction, an inflammation of the surface of the bone and nonspecific indicator of infection, was observed in 6 of the 19 individuals with intact, observable long bones at the naval cemetery. All noted occurrences were sclerotic or remodeled in appearance and suggestive of the bony changes of chronic disease processes or healing phases as described by Buikstra and Ubelaker (1994:118). None appeared to have been active at the time of death. Four of the 15 sailors with intact tibiae had evidence of periostitis of the shaft of the bone. Two of the 19 individuals with at least one observable femur displayed periostitis of the shaft of the bone. A fifth individual’s frontal bone was affected.

The presence of vertebral osteoarthritis, an age and activity-related degenerative change of the vertebral column, was observed in 3 of the 14 individuals with at least one observable vertebra. These three were among the older individuals within the naval cemetery sample. The most severe of these occurrences (Burial 22) was a cervical vertebra with a sharp degree of lipping around approximately one-half of the body and significant osteophytic growth. Two of the 15 individuals with at least one observable innominate displayed bilateral osteoarthritic changes of the superior and posterior margins of the acetabulum or hip joint.

Schmorl’s nodes, small depressions in the bodies of vertebrae, are an indicator of vertebral disc herniation and were present in 6 of the 14 individuals with observable vertebrae. These defects ranged from small, shallow circular depressions of 1 to 2 mm diameter to large irregular depressions of the articular surfaces of vertebrae that measured 10 to 12 mm in diameter and 2 to 3 mm in depth (Figure 5). Muscle attachment hypertrophy (enthesopathy), a cellular change in bone usually associated with physiological stress, was observed in three of the sailors. The supinator crest of the ulna, an attachment for the supinator muscle that is involved in lateral rotation of the forearm, was affected in 2 of the 12 individuals with at least one observable ulna. These bony changes manifested themselves as pronounced ridges at the site of muscle attachment. The deltoid tuberosity (the attachment for the deltoid muscle) of the humerus of 1 individual of the 14 members of the sample with observable humeri was also affected.

Two of the 8 individuals with observable skulls within the naval cemetery sample displayed evidence of the orbital lesions of cribra orbitalia, a condition commonly associated with anemia. These lesions appeared as slight to moderate orbital porosity and appeared to have been either healed or inactive at the time of death (Table 1).

**Stature**

Eleven stature estimates were obtained from the group, ranging from 5 ft. 6 in. to about 6 ft. 1/2 in. All stature estimates were based on the maximum length of the femur. A mean stature of about 5 ft. 9 in. was derived.

![FIGURE 5. Burial 38, Schmorl's nodes of thoracic and lumbar vertebrae. (Photo by William D. Stevens.)](image-url)
Dental caries, along with tooth loss, abscess, and periodontal disease, are a widespread pathology among the sample, as is common among 19th-century groups. Twenty-one percent of the total teeth in the sample, representing 19 sailors, were carious. These lesions ranged in degree from small circular, eroded lesions of the tooth surface to complete destruction of the tooth crown with exposure of the tooth root (Figure 6). The mean number of caries per mouth was 6.63.

Linear enamel hypoplasia (LEH), a developmental defect of the tooth enamel linked with childhood malnutrition and febrile illness, was the most frequently observed pathology in the Confederate Naval sample. It occurred in 94.7% of the group (18 of 19 individuals with observable teeth). These enamel defects appeared as horizontal, linear grooves of the labial or anterior surfaces of the incisors, canines, and premolars of varying width and depth (Table 2).

### Table 1

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<tr>
<th>Burial No.</th>
<th>Estimated Age</th>
<th>Periostitis</th>
<th>Arthritis</th>
<th>Schmorl’s Nodes</th>
<th>Cribra Orbitalia</th>
<th>Healed Fracture</th>
<th>Muscle Hypertrophy</th>
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### Dental Pathology

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### Discussion

Skeletal Pathology

The near complete absence of evidence of trauma within the naval sample contrasts starkly with other historic military samples that display frequent evidence of traumatic injury (Sciulli and Gramly 1989; Owsley et al. 1991). Preservation conditions have probably caused an under-representation of the true amount of skeletal pathology, as has the likelihood that many of the sailors died due to illness. Nonetheless, the absence of skeletal trauma within the sample echoes the historical observation that disease caused far greater mortality during the Civil War than battle wounds.

The presence of a significant degree of periostitis among the sailors, especially in the lower limb bones, suggests that they had endured frequent and probably severe bouts of illness during childhood and adulthood. Although no acute or localized patterns were observed in the
distribution of lesions, it is possible that some may have been the result of skin ulcerations resulting from typhoid fever as described by Paul Steiner (1968:78). The body-wide abscessing associated with dysentery is another possible source of periosteal reaction (Brooks 1966:116). In addition, daily shipboard activities such as scaling ladders and masts would probably have exposed sailors to numerous, recurrent minor traumas to the arms and legs, contributing to some of the observed periostitis. Another likely source of periostitis in the naval cemetery sample is the subperiosteal hemorrhaging of the lower limbs associated with scurvy.

Although it is somewhat infrequent in occurrence, the presence of osteoarthritis within the sample is informative. The biomechanical stress experienced by the sailors due to frequent heavy lifting, manual labor, and a generally demanding occupation are likely causes of osteoarthritis. Traumatic origins cannot be excluded, as the daily activities of sailors are likely to have exposed them to falls and other impact injuries.

The posterior and superior margins of the acetabulum are common locations for arthritic changes since the hips are major weight-bearing joints. Degeneration of these margins is probably attributable to lifting strains among other stresses. Historical accounts indicate

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**TABLE 2**

<table>
<thead>
<tr>
<th>Burial No.</th>
<th>Estimated Age</th>
<th>Periodontal Disease</th>
<th>Caries</th>
<th>Antemortem Tooth Loss</th>
<th>Abscess*</th>
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that lifting activities were a common part of the routines of naval men. Heavy lifting was required both on- and offshore in the operation of heavy artillery, the shoveling of coal for the stoking of steam engines, and doubtless in the repair of frequently damaged bunkers and shore fortifications. Repair efforts likely involved the movement of heavy logs, sandbags, and stone.

The relatively high rate of Schmorl’s node formation among the group can also likely be attributed to the physical strain and subsequent herniation associated with heavy lifting and trauma to the vertebral column. Possible prewar agricultural, maritime, or industrial occupations are other potential sources of herniation of the vertebral discs.

The presence of muscle attachment hypertrophy of the limbs of the sailors, although limited in expression, indicates increased musculature among the men. If some of the individuals were not already muscular prior to naval service, this condition is likely a result of their demanding occupations. Many nautical activities are likely to have placed considerable stress on the muscles of the upper body and arms. Strenuous, repetitive activities like rowing probably led to great increases in upper body strength and resultant hypertrophy of muscle attachment sites.

The block and tackle systems associated with sails and heavy gun carriages, as well as the hauling of lines and chains, are also likely to have placed considerable upper body strain on the sailors. Numerous shipboard activities must have also required medial rotation of the arm; one of the proposed causes of supinator crest hypertrophy (Kennedy 1983:873). Work with ropes, pulleys, capstans, and winches requires this form of physical exertion.

The presence of healed lesions of cribra orbitalia among the naval remains is suggestive of childhood anemia resulting from parasitic conditions or chronic childhood diarrheal illness—both common 19th-century disease patterns. Dietary deficiency and iron absorption problems are other possible causes of cribra orbitalia. As cautioned by Charlotte Roberts and Keith Manchester (1997:171), it is important to note the frequent confusion of the orbital lesions of cribra orbitalia with those of scurvy. Although orbital porosity is characteristic of the former and orbital new bone formation of the latter, it is possible that they are virtually indistinguishable in the sailor sample. Erosion and poor preservation affected almost all of the cranial material and have likely altered the original appearance of most lesions. The high incidence of scurvy among Civil War period sailors and soldiers, especially those in the coastal South, makes the disease worthy of consideration as a possible cause of the observed orbital lesions (Tables 3–5).

**Stature**

The group seems slightly tall for the time period and may display evidence of factors such as military selection in recruiting. No published height selection criteria for the Confederate Navy were found. The sailors and marines are taller than contemporaneous West Point cadets (Komlos 1987:901). Although the sample size at the naval cemetery is indeed small, the perceived tallness may also be the result of the decreased pathogen load experienced by those of rural birth when compared to urban-born individuals, occupational factors, or resource access as suggested by other researchers (Margo and Steckel 1983:172–173; Costa and Steckel 1997:63). Considering the historical mention of drastic shortages of sailing experience within the Confederacy, it is doubtful that naval recruiters were overly selective.

**Dental Pathology**

Considering that many of the sailors were probably Irish immigrants, it is notable that the percentage of dental caries within the sample (21% of the total teeth in the sample) is very close to the rate observed among the British Spitalfields Project sample (Whittaker 1993:51). The latter sample is comprised of Londoners buried at Christ Church, Spitalfields during the early-18th to mid-19th centuries. Although the Spitalfields sample is largely of middle-class origin, its time period encompasses that of the birth years of the naval cemetery sample and may suggest similar influences stemming from the carbohydrate-rich dietary patterns of the British Isles. The highly cariogenic diet of the sailors consisted of cornmeal, wheat flour, salted meats, and both liquid and granular forms of sugar.
### TABLE 3
SKELETAL INVENTORY BY NUMBER OF OBSERVABLE ELEMENTS

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<th>Burial No.</th>
<th>Cranium</th>
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<th>Clavicle</th>
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### TABLE 4
SKELETAL INVENTORY BY NUMBER OF OBSERVABLE ELEMENTS

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The high percentage of caries located on areas other than the chewing surfaces within maxillary incisors and premolars is somewhat unusual. The frequency of caries among incisors within the sample is significantly greater than those rates reported for other 18th- and 19th-century military samples (Sciulli and Gramly 1989:21; Sledzik and Moore-Jansen 1991:217). An interesting phenomenon that may serve to explain a large percentage of these defects is the co-occurrence of carious lesions and the developmental defect, LEH. Nonocclusal caries and LEHs occurred simultaneously on teeth in 52.6% of individuals at the naval cemetery. The apparent tendency of these defects to predispose incisors and canines to carious lesions has been noted within contemporaneous 19th-century poorhouse samples (Higgins and Sirianni 1995:126).

Observations from modern clinical practice in South Carolina reveal further possible factors of influence in the high rates and unusual distributions of nonocclusal caries found in the sample. Similar high rates of anterior interproximal caries are often associated with the consumption of sweet liquids, sugars, and sweets (John L. Edwards 2000, pers. comm.). The southern traditions of drinking sweet tea and chewing on sugar cane are likely to have led to significant interproximal calculus buildup and subsequent high rates of caries. Elevated caries rates in anterior teeth have also been attributed to the southern habit of sucking lemons during hot weather (Ted A. Rathbun 2000, pers. comm.). Although speculative, it seems likely that habits such as these would have been prevalent during the Civil War, especially with dietary shortages of vitamin C and the concern about scurvy.

The LEH rate within the sample is notably higher than those reported within other historic period North American skeletal samples and is likely reflective of the high frequency of malnutrition stress and the childhood febrile illnesses of the period. The mean number of LEH defects per mouth among the sailors (3.83 based on mandibular canines) was greater than
that of other historic skeletal samples (Angel 1976:731; Larsen et al. 1995:149; Winchell et al. 1995:165). Mumps, measles, chicken pox, scarlet fever, erysipelas, and whooping cough were frequent causes of childhood illness and early mortality during the era. The frequent and severe expression of these defects within the groups represents exactly the type of highly stressful childhood that should be expected for a population that probably experienced the chronic food shortages of the Potato Famine. Comparisons of the naval LEH data with that of contemporaneous Irish skeletal samples could prove informative and, if available, will be the subject of future comparative study.

Rank-Based Differences in Health Status

No significant differences in health or disease experience were evident between those individuals of presumed higher rank or status and the lower ranking members of the sample. Again, these assessments were based on accompanying archaeological evidence in the form of coffin types, uniform buttons, and gold dental restorations. Evidence of a stressful life, especially during childhood, was uniform throughout the sample. In addition, small sample sizes hinder the ability to make any meaningful intrasample comparisons.

Conclusion

The burial recovery project at the Confederate Naval Sailor and Marines’ Cemetery has provided the rare opportunity to study Civil War period military skeletal remains. Despite the comparative modernity of the Civil War era, many questions surrounding the period remain unanswered. In addition, many forms of evidence pertaining to the southern role in the Civil War, such as health and mortality records, have been lost or destroyed since the period.

The skeletal data support an image of the Confederate sailors as individuals who endured significant childhood nutritional and disease stresses and probably held physically demanding occupations prior to and during the Civil War. Despite the limitations of small sample size and poor preservation, meaningful inferences can be drawn regarding the health and occupational stresses experienced by the sailors.

The dental data recovered from the Confederate sailors are by far the most complete source of biological information within the sample. These data offer great potential for comparison with contemporaneous samples. The tooth size data could facilitate population affinity studies and possibly establish more conclusive genetic links to the Irish population of the time period. Similarly, a more detailed examination of the abundant linear enamel hypoplasia data may permit informative comparisons with similarly highly stressed populations and any available Irish data from the period.

Finally, research has not simply corroborated the historical evidence pertaining to Confederate sailors and marines. Rather, it has informed the historical picture of this group by revealing health and occupation-related phenomena not mentioned within the historical record.

Acknowledgments

The authors wish to thank Ken Kelly and Tom Leatherman for their great efforts, assistance, and advice. For the opportunity to publish this paper, we thank Julie Schablitsky. We especially thank Ted Rathbun, without whose patience and expertise the project would not have been possible. For the opportunity to excavate and analyze the Confederate Naval Sailor and Marines’ Cemetery remains, along with his insight and assistance with all aspects of the project, we thank Senator Glenn McConnell. Senator McConnell is an ardent proponent of historic preservation throughout South Carolina, not to mention an excellent hand with both shovel and trowel. Citadel President Major General John Grinalds and the Citadel staff permitted the work on Citadel property and took a personal interest in seeing its successful conclusion. We are also deeply indebted to all those who provided assistance and advice: Randy Burbage, Kay Long, Mark Ragan, Joanna Casey, John Edwards, Jean Massey, Dorothy O’Dell, Brian Stevens, Deane Stevens, Erin Christo, Amanda Colton, Jennifer Massey, and Jill Olsen. Last but never least, we wish to thank the 300 volunteers and the people
of Charleston who at every turn anticipated our needs and provided for them.

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STIRLAND, ANN  

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The Man in the Iron Coffin: 
An Interdisciplinary Effort to Name the Past

ABSTRACT

The examination of a cast-iron coffin from the Mason family cemetery at Pulaski, Tennessee, offered an exceptional opportunity to study relatively well-preserved human remains, associated artifacts, and the coffin itself. Only a few studies of cast-iron coffins and their contents have incorporated the results of interdisciplinary research in the interpretation of the burial and the remains. The investigation is based on the use of an evolving protocol that promotes the collection of relevant information from several disciplines when evaluating cast-iron coffins and their contents. Multiple lines of evidence identify the remains as those of Isaac Newton Mason, a private in the First Tennessee Confederate Cavalry Regiment, and provide a detailed and intimate glimpse into the past.

Introduction

Information on the past, its people, and the societies in which they lived can be obtained from many archaeological contexts. Among these, human burials and related artifacts provide an intimate view of the society represented and the individual involved. Unfortunately, the preservation of buried human remains and artifacts is variable and can be greatly reduced over time.

In North America, one of the best burial containers manufactured for the preservation of human remains and their associated artifacts was the cast-iron or metallic coffin. Cast-iron coffins were introduced during the 19th century as wooden coffin manufacture shifted from traditional hexagonal coffins to more elaborate designs in response to a social movement toward the beautification of death (Little et al. 1992). After the War of 1812, interest in preserving the body grew and, at the same time, coffin making moved from urban cabinetmakers to commercial burial case manufacturing. Although many industrial coffin manufacturers introduced “body preserving” coffins made out of iron, zinc, and clay, one of the most innovative and popular designs was made of cast iron (Crane, Breed & Co. 1858, 1867).

Almond D. Fisk’s cast-iron coffin, patented in 1848, was one of the first iron coffins to advertise an airtight environment. The coffin design incorporated protruding flanges encircling both the top and bottom portions that were joined with a lead seal and then bolted together. This created an excellent anaerobic environment conducive to superior human tissue preservation, which was also being promoted by more sophisticated embalming techniques.

Because of the outstanding preservation afforded by these burial containers, the correct recovery and careful examination of cast-iron coffins and their contents offer an exceptional opportunity to obtain information on social customs, dress, and health, including nutrition, disease, trauma, and activity patterns. Fields of research that can contribute to these investigations include forensic anthropology (osteology), forensic pathology, historical archaeology, historiography, costume history, and genealogy.

To date, studies of iron coffins and their contents have been limited. Opportunities to examine cast-iron coffin burials have been rare, in part because the costly coffins were restricted to use by the wealthy (Owsley and Mann 1995; Owsley and Compton 1997; Rogers et al. 1997; Bass and Jefferson 2003). Complete study is also often precluded by external damage brought on by vandalism or construction-related mishaps.

This study began when excavation of a private 19th-century cemetery revealed an unknown and unmarked grave that contained a cast-iron coffin (Figure 1). Coffins in this multifamily cemetery near Pulaski, Tennessee, were to be disinterred and reburied in another location. The Mason family descendants wished to establish the

Permission to reprint required.
identity of the individual in order to properly mark the new grave and thereby complete the inventory of burials in their section of the relocated cemetery. Therefore, the coffin was transported to the Smithsonian Institution’s National Museum of Natural History (NMNH) Anthropology Conservation Laboratory for the examination of its contents. The purpose of this study was twofold: to derive as much information as possible from every aspect of the burial, utilizing a multidisciplinary approach, and to obtain a personal identification of the deceased.

**Methods and Laboratory Procedures**

The multidisciplinary approach to the investigation of this burial required scheduling a time when all specialists—pathologist, osteologist, costume specialist, genealogist, and historian—could be together for the opening of the coffin. Therefore, before the coffin was brought to the Smithsonian, it was temporarily reinterred in the new cemetery until arrangements could be made and a standardized protocol developed for its examination. A sheet of plywood was placed directly on the coffin in the temporary grave as a soil barrier to facilitate removal and help protect the aged metal casket. Unfortunately, a special feature of the coffin defeated part of the planned protection during the temporary reburial. The coffin design incorporated a glass viewing plate over the face of the deceased. The viewing window was comprised of a plate of sealed clear glass with a removable metal cover. The viewing plate cover was the highest point of the coffin, and the plywood used to cover the coffin rested directly on it. When the grave was filled, the pressure from the weight of the soil on the plywood broke the metal cover which, in turn, cracked the glass viewing plate (Figures 2 and 3). During the ensuing year,
moisture from the surrounding waterlogged soil seeped into the coffin.

In April 2003, the cast-iron coffin was transported to the NMNH in Washington, DC, and was in apparent good condition despite its extraordinary arrival weight of 311.6 kg (687 lbs.). The heavy weight was the result of water that had completely filled the coffin during the temporary interment period. In order to open the coffin and proceed with the analysis, a small hole (1/4-in. diameter) was drilled into the base to drain the water. Later, with the water drained and the contents cleaned and returned to the coffin for its return to Tennessee, its weight was 97.5 kg (215 lbs.). Once the coffin was drained, the bolts connecting the coffin body and lid were drilled out and the lid removed.

The analytical plan followed during this examination is outlined in Appendix A. This interdisciplinary approach involved a pathologist responsible for autopsying the remains, including toxicological and microbiological testing, and osteologists who conducted the forensic anthropological examination. In addition to determining age, sex, and race, the specialists examined the bones and teeth for evidence of injury, disease, and indicators of habitual activity. Extensive photography, computed tomography, and selected radiography of the bones documented and aided this assessment. Small quantities of bone were removed for stable carbon and nitrogen isotope analysis to collect information about diet. A costume specialist supervised the removal of the clothing as well as its cleaning and detailed examination. The coffin and its hardware were examined by an historical archaeologist. The final step was comparison of the biological and archaeological data with the historical and genealogical record in order to establish personal identification.

Results

The primary results of this investigation are summarized below. Additional details on specific components of the analysis are presented in Appendix B.

Coffin

The burial container is a “torpedo-shaped” Fisk metallic coffin, Plain Case Model No. 3, manufactured by Crane, Breed & Co. (1867; Allen 2002a; 2002b). The Fisk Plain Case cast-iron coffin was patented in 1858 (Habenstein and Lamers 1955) and remained popular throughout the Civil War. A glass viewing plate with its removable metal cover is at the head end of the coffin lid; both the glass and the metal cover are in the shape of what is known as a lancet window, which has a narrow, pointed arch. The metallic plate was broken into 16 pieces by the weight on the plywood sheet used during the temporary reinterment. The glass viewing plate beneath contained a large crack that extended diagonally across its entire length and additional smaller cracks at either end.

The hardware found on the coffin included swing-bail handles and slotted-head bolts that are indicative of the 1850s and 1860s. Use of slotted-head bolts diminished after 1877 (Allen 2002a). This diagnostic hardware suggests coffin manufacture between 1858 and the 1860s.
The cost of an iron coffin was substantial. Wholesale prices in 1867 for adult-size Plain Case coffins ranged from about $30 to $53 (Crane, Breed & Co. 1867), significantly higher than traditional wooden hexagonal coffins (Habenstein and Lamers 1955). The fact that this individual was buried in a cast-iron coffin indicates the individual or family had some degree of wealth.

Human Remains

The iron coffin contained a fully clothed and well-preserved skeleton (Figure 4). The computed tomography (CT) scans revealed the preservation of about 200 g of brain tissue and extensive disarticulation and disarray of the bones within the thorax, in addition to clothing-related items such as buttons (Figure 5). Imaging facilitated removal of the clothing and helped determine the course of the rest of the examination, as it showed that the organs and other soft tissues had almost completely decomposed. The CT scans also revealed that the disarticulation was due to postmortem shifting of the bones incurred during movement of the water-filled coffin, rather than injuries sustained by the individual at the time of death.

Forensic pathology sampling was conducted to obtain evidence of disease and drugs or toxic chemicals in the human tissues and burial environment. Despite the advanced stage of soft tissue decomposition, information about the individual’s life and death was obtained. Cultures taken at the time of the coffin’s opening revealed non-pathogenic soil organisms including a spore-forming bacillus species. No disease-producing pathogens were identified that would have contributed to this individual’s death. The laboratory examination of brain tissue for strychnine and arsenic was negative, ruling out embalming practices in which arsenic was prevalent—from approximately 1860 to 1910. Radioimmunoassay analysis of the hair revealed cotinine, a metabolic product of nicotine. The level of cotinine is consistent with tobacco use. Opiates were not found in the hair. Although the test was negative for opiates, the results do not confirm that this individual did not consume morphine for pain relief or recreation, only that the test did not detect an opiate in the hair sample.

A biological profile was established for the individual using standard methods of data
collection for skeletal remains. Osteological examination of the bones and teeth determined the individual to be a Caucasian male, aged 33 to 37 years old at death, and approximately 5 ft. 10 in. tall. The remains of fine, medium-brown hair recovered from the head end of the coffin supplemented the individual’s profile.

The dentition shows extensive pathology. Eight teeth were present in the maxillae at the time of death; eight maxillary teeth, including five molars, were lost before death and their sockets had fully remodeled. Two of the remaining teeth have cavities; three have periodontal abscesses. Thirteen mandibular teeth were present. Both first molars and the right second molar were lost before death, and their sockets had completely remodeled. Eight mandibular teeth have cavities, two so severe that the pulp chambers are exposed and the sockets are abscessed. The right lateral incisor socket is also abscessed although the tooth is not decayed.

Loss of molars would have made chewing more difficult. This would have been exacerbated by degeneration of the temporo-mandibular joints and the mandibular condyles, which show pitted-type porosity and remodeling. Antemortem erosion had greatly reduced the joint surfaces of the condyles, resulting in a hypoplastic condition that, not unlike the dental abscesses, was likely an aggravating source of discomfort in life.

No pipe-wear facets are present, although dark staining from tobacco use is evident. In addition, calculus buildup was heavy, especially on the anterior dentition. Heavy calculus, tooth decay, periodontal disease and resorption, and only slight levels of tooth wear indicate a non-abrasive, cariogenic diet, poor oral hygiene, and a lack of dental care.

Diet was further defined through stable carbon and nitrogen isotope analysis. Chemical analyses of bone for stable carbon and nitrogen isotopes have proven useful for interpreting dietary patterns of past and present peoples and organisms (Vogel and van der Merwe 1977; van der Merwe and Vogel 1978; Ambrose and DeNiro 1986; Keegan 1989; Buikstra and Milner 1991; Tieszen et al. 1992). The method is based on differences in the isotopic composition of plants due to environmental variations of climate and aridity. The different carbon and nitrogen isotope values at this initial level of the food chain are transferred to the tissues of the consumer (animal or human). General dietary patterns are defined by measuring these isotopic differences with the results presented as δ¹³C (delta carbon) and δ¹⁵N (delta nitrogen) values in parts per million (‰).

The positive stable carbon and nitrogen isotope values obtained from this man’s bone (δ¹³C value of -10.53‰ and a δ¹⁵N value of 10.99‰) indicate a diet based on plants and moderate levels of animal protein. Plant foods the man ate would have primarily been those using the C4 photosynthesis pathway, probably corn, sorghum, and sugar. Assuming the man lived near his burial place in Tennessee, corn would have been a dietary staple and, being high in carbohydrates, would have contributed to a cavity-causing, plaque-inducing diet. The indicated level of protein obtained from the nitrogen isotope data is consistent with values of individuals identified as American born and raised (Ubelaker and Owsley 2003).
The general condition of the bones indicates good skeletal health. With the exception of the temporo-mandibular joints and slight vertebral arthritis, few pathological changes are noted. The skeletal changes that are documented for this individual do not reflect disease but, rather, are markers of habitual activity. In general, slight to moderate development of the muscle-attachment sites on the bones of the arms and legs indicate this individual participated in only a moderate degree of heavy labor. More specific review of the bones reveals several activity indicators related to horseback riding. These are not the skeletal modifications of a recreational rider but of someone who rode often over a lifetime. For instance, the left and right acetabulae show slight superior elongation, a common trait among long-term horseback riders (Erickson et al. 2002). The gluteus muscle-attachment sites are defined on the ilia. The gluteus maximus extends the hip in order to keep the individual upright in unstable conditions, such as horseback riding (Capasso et al. 1999). The femora have Poirier’s facets, which are formed by the continual spreading of the thighs while on horseback. Common in horseback riders is the development of rotational tissues that attach to the lesser trochanter (Capasso et al. 1999). This development is seen in the attachment ridges of the ilio-femoral ligaments, which are raised and clearly defined on the proximal femora. Slight lipping is also noted on the distal joints of the femora as well as the head of the right femur on the joint margin. The tibiae have well-defined soleal lines on the posterior proximal surface, commonly seen as the result of using calf muscles while riding horses. In addition, multiple thoracic vertebrae display depressions in their centra, identified as Schmorl’s depressions, or herniations of the vertebral endplates (Figure 6). These degenerative changes were caused by vertical compression. In this case, a contributing factor was likely the characteristic sitting position of a horseback rider, which can exacerbate the tolerated level of impact on the spine (Capasso et al. 1999).

Despite the skeletal evidence for activities during life, no cause of death could be determined from gross visual and radiographic analysis of the human remains. Gunshot wounds or bladed injuries that kill by entering vital organs often also strike bone; there were no such marks on this skeleton. Fractures of the skull and postcranial skeleton are also absent as are changes in bone indicative of disease processes such as cancer, long-term infection, or tuberculosis.

The only hard tissue evidence that may relate to the circumstances surrounding this man’s death is present in the four fingernails recovered from the coffin in the region of the finger bones. No other fingernails were recovered, a loss not resulting from decomposition of the nails themselves but possibly due to the fact that nails become loose during the early stages of soft tissue decomposition. The nails can then be dislodged when handling or moving a body. The few fingernails that were collected may indicate that a period of time elapsed between the death of the individual and the transfer of the body into the coffin.

Clothing

The individual was dressed in men’s clothing. He was wearing a black broadcloth, fully lined, single-breasted frock coat of standard construction (Figure 7). This tailor-made coat has a fitted back, a quilted collar and lapel lining for a smooth fold line, and a skirt with a vent opening in the center of the back. A small rectangular hole in the right front skirt of the coat near its bottom had been neatly mended with a patch. The back of the coat has an intentionally made vertical slit that was not part of the coat construction.

![Multiple thoracic vertebrae display Schmorl's depressions.](http://example.com/image.jpg)
Loose masses of thread present throughout the chest and back region are believed to represent a deteriorated vest that most likely had a wool front and silk back. Silk fabric, bowed and tied as a necktie, is still present (Figure 8). Although there is no surviving cotton fabric, presumably this individual would have been buried wearing a white cotton shirt. As evidenced from earlier investigations, the protein-based fibers of wool and silk survive in better condition than the cellulosic fibers of cotton (Ballard 1996).

The tailor-made trousers have a concealed five-button fly with an additional button at the top of the waistband. Two sew-through buttons with well-preserved yellow gilt at the top of the posterior waistband are probably for suspender use. The trousers were constructed with a center back seam and a pieced yoke for fitting, producing a relatively rectangular silhouette. The back of the left leg of the trousers has a slit measuring 2-1/8 in. that was intentionally made with scissors or a knife. The side seam of the right pant leg was also intentionally opened almost its entire length, from the hem to approximately crotch level.

In addition to the tailor-made suit, this man was wearing a pair of expensive, good quality riding boots (Figure 9). This style of high-top boot, possessing a narrow waist with a comparatively high stacked heel, is typical of boots made after 1840 and was common during the Civil War period and later. This boot style was used by both civilians and military personnel.

Black broadcloth frock coats with trousers first appeared about 1816 for less formal wear; by
1850, they were acceptable for most occasions (McClellan 1910; Waugh 1964:113–114). The single-breasted coats of the earlier part of the 19th century gave way to double-breasted ones by the 1860s. Given that this suit had been mended on the skirt, it was most likely worn for several years prior to the individual’s death. A tailor-made suit, even if slightly worn and dated, with a silk and wool vest and silk necktie indicates a relatively high social status. The expensive boots show that riding was an important part of this man’s daily life.

In addition to reflecting class and occupation, this individual’s clothing reveals information about his death. Modifications in the clothes and the presence of boots suggest a lapse of at least a few days prior to the body being prepared for burial. Such preparations, usually done in the home, would have included removing work or field clothes and redressing the man in his suit. Tears and cuts in both the frock coat and the trousers suggest dressing a body already entering the early stages of decomposition. A slit that runs the entire back mid-seam of the coat (Figure 10) was intentionally made and would have provided an easier way to dress the deceased, whose body would have been swollen by tissue gases (bloating) (Clark et al. 1997). The slit would have broadened the width of the coat so that one arm could be inserted and facilitated further extension to allow insertion of the other arm.

Modifications of the pant legs suggest dressing over the boots. Swelling and skin slippage would have made it difficult to replace these high-top boots once removed. The small tear at the cuff made it easier to pull the left pant leg up over the boot. The right pant leg was opened at the seam and wrapped around the leg. Boots are uncommon in historic burials due to their cost, and this pair was in good condition at the time of burial, especially considering the burial was in a Southern state. If this individual died during the Civil War, the boots suggest a death early in the war years since most surviving examples of Confederate-era boots are extremely worn due to the difficulty in obtaining new ones (June Swann 2003, pers. comm.).

Discussion

The results of the laboratory analysis identify the individual in the iron coffin as a white male, 5 ft. 10 in. tall, of medium build, aged 33 to 37 years old at the time of death. He was of relatively high socioeconomic status based on his burial container, clothing, and skeleton, which suggested he experienced only a moderate degree of heavy labor and had a diet with moderate levels of protein. He was an experienced equestrian based on activity-induced bony changes and the presence of good quality riding boots.

Perhaps one of the most intriguing results of the laboratory analysis was the evidence for this man’s burial several days after his death. Evidence in the form of modifications in his clothing and the absence of fingernails suggest a period of a few days elapsed between death and preparation for burial.

In order for a personal identification to be made, the biological and artifactual data described above had to be merged with the

FIGURE 10. The coat was halved by a large slit that ran up the back. (Photo by Chip Clark, National Museum of Natural History, Smithsonian Institution.)
historical and genealogical information on the Mason family of Pulaski, Tennessee. Review of the historical information about the cemetery shows the location of Burial 30 in close proximity to the marked graves of the Mason family. As Mason family members died, they were buried in the northern part of the cemetery and subsequent interments progressed toward the south. The burial plan appeared to be that the children of Isaac Mason (Sr.) (Burial 7) and his wife Nancy Edwards Mason (Burial 6) would be positioned around their parents (Figure 11). This is evidenced by the apparent reservation of space for the children of Isaac Mason as interments progressed southward. Burial 30 (Figure 12) was positioned immediately south of Isaac Mason (Sr.) and adjacent to some of his sons and other close relatives (Allen 2002a). This placement suggested that the individual had a close familial relationship with Isaac Mason.

In total, Isaac Mason (Sr.) had 10 children, two of whom died in infancy. Of the remainder, all boys, Benjamin Washington Mason and Carson T. Mason were buried in Maplewood Cemetery, Pulaski, Tennessee. Joseph G. Mason was buried in Prospect, Tennessee, and Winfield S. Mason was buried in Alabama. Gustavus, Albert, and James, who died between 1858
and 1865, were buried in cast-iron coffins with marked graves in the Mason Cemetery (Allen 2002a). The remaining son, Isaac Newton Mason was believed to have been buried in the family cemetery, but no grave site was known. Isaac Newton Mason of Giles County, Tennessee, was born on 8 June 1826. Historic records list his holdings as 1,640 acres of land, farming equipment, 27 slaves, and a host of mules, cattle, and hogs. Isaac Newton and his family would have been considered wealthy before the Civil War. The 1860 U.S. Census valued his real estate at $19,299 and personal property at $23,865 (Johnson 2003). Much of Mason’s personal property was taken or destroyed during the war by the Federal army and roving bands of thieves. An 1867 Giles County Chancery Court case lists Mason family wartime losses as including 130 acres of corn, 60 head of hogs, 6 horses, 4 mules, 23 head of cattle, 26 stacks of fodder, 2 horse wagons, and all farming equipment (Johnson 2003). In December 1861, Isaac and his brother Albert enlisted in the Confederate Military as privates in the 11th Tennessee Cavalry Battalion, 6th (1st) Tennessee Cavalry Regiment (Johnson 2003). The brothers participated in the Battle of Shiloh in April 1862. Isaac Newton Mason is reported to have died in April or May of 1862 at the age of 35 years, although the records are unclear as to how, when, and where he passed away. One document indicates that he died from injuries incurred during a fall from a train near Iuka, Mississippi (Nelson 1908). Isaac was reportedly taken to a hospital in Tuscumbia, Alabama, although there is no record that he was treated there.

If Isaac did die as reported, how his body was returned to his home is unknown. Such an event was rare in Giles County, as nearly 800 soldiers from this locality died during the war and less than a dozen were brought home for burial (Bob Wamble 2004, pers. comm.). If the body was brought home from Tuscumbia, it traveled over a distance of nearly 80 miles on poor winding roads under Union control. A best estimate suggests that at least three days were required for the trip (Bob Wamble 2004, pers. comm.).

The history of Isaac Newton Mason, even the uncertainties or gap in the historical record about his death, offers several points of correspondence with the biological and social profile of the man in the cast-iron coffin. His age, social position, and lifestyle, as defined through the historical record, are supported by the results of the laboratory analysis in nearly every respect. Some of the circumstances of Isaac N. Mason’s burial were revealed in the laboratory study. Although no bone injuries were evident, an elapsed time between death and burial is indicated.

Figure 13. A reconstruction of the face of Isaac Newton Mason was completed by John Gurche.

Conclusion

Determining the identity of a decomposed, skeletonized individual is a challenge commonly faced by forensic anthropologists in contemporary medico-legal investigations. It is even more challenging to apply these investigative techniques to remains of individuals from the past. As a result of uncertainties in the burial record and variable effects of preservation, under the best of conditions it can be difficult to recover enough bones to reconstruct even a partial skeleton and to confirm identity of historic remains.
The cast-iron coffin from the Mason Family cemetery offered a unique opportunity to name the past through the examination of one who lived it. The analysis of the human remains and artifacts was aided by the use of a burial container that resulted in good preservation. Multiple lines of evidence were applied to the study of these remains for optimal data collection. The results placed the date of the burial within a relatively narrow temporal span and created a detailed biological and social profile. In combination with historical and genealogical data, enough evidence was obtained to identify the man in the cast-iron coffin as Isaac Newton Mason, a private in the First Tennessee Confederate Cavalry Regiment, from Pulaski, Tennessee (Figure 13).

The research design implemented in this investigation is presented in Appendix A as a suggested guideline for others initiating similar projects. Although this report describes only a single individual and the circumstances of that death, this study has greater relevance for documenting and interpreting mortuary practices and health in the mid-19th-century upper South. Given that the individual died early in the course of the Civil War, it appears that the family had the resources to bring his body home over a considerable distance and provide him with an expensive coffin. This contrasts with the Mason family’s subsequent financial decline, a result of wartime conditions. Within five years of Isaac Newton Mason’s death, his family had lost an extraordinary sum. Because of the financial decline of the South subsequent to the Civil War, burials conducted late in the war would presumably differ and offer an interesting perspective on changes in mortuary customs relative to changing sociopolitical events and regional circumstances. The results of this study also contribute to the recording of standardized health-related and metric data for sample-based comparative research. Specific details required for this type of database research are presented in Appendix B.

Acknowledgments

Guy and Fran Mason represented the family and enabled all phases of this investigation. Claudia Johnson and Fran Mason researched and provided in-depth historical and genealogical information. The cemetery relocation was completed by DuVall & Associates, Inc., of Franklin, Tennessee, Dan Sumner Allen IV, principal investigator. Pulaski attorney, Stan Pierchoski, arranged for the state disinterment and transit permits. Science photographer Chip Clark provided the photographs. The CT scan was taken by Rebecca Snyder. The facial reconstruction shown in Figure 13 was prepared by John Gurche. The scientific team also included forensic anthropologists David Hunt and Ashley McKeown, and assistants Sandra Schlachtmeier and Cass Taylor. The genealogical chart and map of the cemetery were prepared by Marcia Bakry, the latter based on the archaeology field report. Stephen Rogers represented the Tennessee Historical Commission and helped in the disinterment and transport of the coffin to the NMNH. Malcolm and Margaret Richardson provided editorial guidance. Anamay Melmed standardized the stylistic format of the manuscript. Arthur Aufderheide reviewed the scientific protocol and pathology report. Skye Chang’s internship and the isotope analysis were sponsored by the NMNH Research Training Program, Mary Sangrey, coordinator, with funding provided by the National Science Foundation, Grant DBI-02435123. Michele Urie coordinated press relations. Kathy Abbot and Rob Wallace helped arrange funding.

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APPENDIX A
A Protocol for the Analysis of Cast-Iron Coffin Burials

The following protocol was followed during this investigation.

I. Preliminary Steps
A. Describe and measure the coffin.
   1. Make, model, distinguishable marking
   2. Coffin condition and preservation
   3. Visual documentation (photographs)
B. Describe the coffin opening and interior.
   1. Coffin interior
   2. Body preservation and positioning
   3. Type of clothing, textile preservation
   4. Visual documentation (photographs)
C. Collect samples from inside the coffin.
   1. Dirt and/or water
   2. Potential embalming materials
   3. Coffin lining
   4. Coffin sealant

II. Taphonomic Observations
A. Describe soft tissue, bone, and dental preservation.
B. Document special cases of soft tissue preservation (adipocere, brain tissue, calcified cartilage, nails, and hair).
C. Document any postmortem alterations incurred while disinterring or transporting the coffin.

III. Computed Tomography
Computed tomography provides images of the body and associated artifacts to determine material densities in volumetric space. The technology provides a digital record of the individual that can be viewed independently of the body itself.
A. Remove the body from the coffin and create images to evaluate the structure and positioning of soft and hard tissues.
B. Determine the positions of associated artifacts.

IV. Clothing Analysis
A. Describe the textiles and their placement on the body.
B. If possible, remove textiles to expose the body for description and autopsy.
C. Collect samples of the textiles.
D. Clean and, if appropriate, conserve the textiles and shoes.
E. Photograph selected items.

V. Autopsy
Body information is derived from the autopsy procedure (dissection) and from laboratory testing of samples collected during the autopsy.
A. Evaluate soft tissues and determine what will be sampled.
B. Collect soft tissue samples (adipocere, brain, spinal cord, identifiable organs, hair).
C. Conduct laboratory analysis of the samples.
1. Microbiology—culture microorganisms from the collected samples.
2. Toxicology—test for the presence of drugs, heavy metals, and toxic chemicals (e.g., strychnine, arsenic, mercury, lead) present in tissue samples and within the coffin environment.

VI. Cleaning and Conservation of the Bones in Preparation for Examination
Cleaning and conservation must be completed before comprehensive osteological and forensic evaluation can begin.
A. Remove adhering textiles and tissues from the bones.
B. Clean and conserve the skeleton.
C. Collect bone samples—specific bones may be selected for stable isotope and elemental analyses (conservation treatment methods should take this into account).

VII. Osteological Analysis
Depending on preservation, the skeletal analysis may include the following:
A. Complete skeletal inventory and analysis.
   1. Complete the bone inventory.
   2. Complete the dental inventory.
   3. Finalize the inventory information for integration into a computer database.
B. Identify age, sex, and ancestry.
C. Identify pathological conditions.
   1. Examine the skeleton for evidence of infection, traumatic injury (antemortem, perimortem), metastatic disease, muscle pulls and tears (enthesopathies), arthritic changes, anomalies, nutritional status, and anemia.
   2. Document examples of physical exertion and strain such as bone cortical excavations, disk herniations, Schmorl’s depressions, and joint and vertebral arthritis.
   3. Examine the bones for evidence of gunshot wounds, cut marks, or other types of injuries, either antemortem or perimortem.
   4. Examine the skeleton for evidence of congenital and developmental anomalies.

D. Collect cranial and postcranial metrics.
   1. Collect three-dimensional coordinate data for the cranium.
   2. Collect mandibular measurements.
   3. Collect morphometric data from the postcranial skeleton (these measurements provide information about physical size, robusticity, and stature).
   4. Compare the morphometric data with selected 19th- and 20th-century reference samples that provide an appropriate interpretive context.

E. Conduct an oral health examination.
   1. Evaluate the teeth and alveolar sockets for the presence of carious lesions, abscesses, antemortem loss, postmortem loss, enamel hypoplasia, calculus, antemortem chipping and fractures, and staining, such as from using tobacco.
   3. Document task activity wear (e.g., pipe wear facets).
   4. Evaluate and describe dental restorations.

F. Conduct tissue sampling for laboratory analyses.

VIII. Radiography
Use conventional radiography to complete the following:
A. X-ray the dentition and cranium (specific views); these images are used in determining age and dental health.
B. X-ray the humeri, femora, and tibiae (specific views); these images are evaluated for the presence of growth arrest lines and long bone pathology.
C. X-ray designated anatomical and pathological specimens.

IX. Photography
A. Photograph the coffin and its contents including the clothing and human remains (i.e., preserved tissues, skull, dentition, skeletal pathology, and special morphological features).
B. Photograph the skeleton in anatomical position (layout view).
C. Photograph specimens selected for bone sampling (isotopes, mtDNA).
D. Photograph selected artifacts.

X. Stable Isotope Analysis
Collagen and apatite carbon and nitrogen stable isotope values are determined from bone and teeth. Isotope data provides nutritional information and clues as to the place of origin.
A. Collect a tooth sample for the determination of childhood diet.
B. Collect dense cortical bone sample for the determination of adult diet.

XI. Mitochondrial DNA Analysis
Mitochondrial DNA analysis represents a future resource for determining individual identity. This analysis contributes to improved understanding of mtDNA preservation in iron coffin environments. Such information has implications for forensic investigations involving similar situations (e.g., environments where the body is protected in a sealed environment).
A. Select samples for future testing.
B. Conduct mtDNA testing.

XII. Determination of Individual Identity
Often the goal of these investigations is to determine personal identification. This objective requires a merger of forensic/skeletal data, the archaeological record, and historical/genealogical information.
A. Consult with relevant parties (project genealogist and/or historian).

APPENDIX B
Additional Information on the Coffin and Its Contents

Coffin

The maximum length of the coffin is 182.9 cm. Its maximum width is 61.2 cm including the protruding flange that is 2.4 cm wide and surrounds the entire exterior at the joint where the top and bottom halves meet. The head end of the coffin is 36.7 cm wide, as measured from the inner side of the top handle lug. The toe end of the coffin is 27.6 cm wide. The height of the sealed coffin is 32.3 cm at the midsection, 31.1 cm at the head end, and 28.0 cm at the toe end. The height of the coffin body, or bottom half, is a uniform 12.7 cm.

The upper half, or lid, of the coffin features three continuously beveled tiers, pyramiding to a flat top surface. The lower half of the coffin, or body, has two faceted panels that gently bevel in toward the bottom. The eight cast-iron handles present are a swing-bail style and are secured by round-head stove bolts with slotted heads. The handles have concave backs. This style of handle is typical of burials prior to the 1880s (Allen 2002a:92). Four handles are attached to the coffin with the smooth convex side outward. Two other adhering handles were mounted with the concave back facing outward. Two of the handles had become detached from the coffin. There are 16 bolts connecting all handles. The head diameter of the mounting bolts is 1.3 cm, the length of the bolts is 3.4 cm, and the bolt shaft diameter is 0.7 cm. The handle lugs are 3.6 cm long and 3.1 cm high. The handle itself is 13.1 cm long. The height
of the bail arm is 6.2 cm with the narrow end measuring 2 cm and the widest point in the center measuring 3.2 cm. Six additional round-head stove bolts, smaller than those used to secure the handles, were used to attach the coffin lid to the coffin body. The bottom coffin flange was drilled and threaded so no nuts were used with the represented bolts.

The metal cover for the glass viewing plate is 48.5 cm long with base and midpoint widths of 20.5 cm. It is secured with five screws: two at the end with square corners, one on either side of the plate at its midpoint, and one at the pointed end. The glass viewing plate measures 41.2 cm long, 15.1 cm wide at the midpoint, and 14.5 cm wide at the squared end.

**Autopsy**

Data collection for the analysis of the human remains was guided by a specially devised protocol that parallels the approach used in modern forensic cases involving the identification of individuals represented by bodies showing advanced decomposition. As part of this protocol, standard autopsy procedures were followed as determined by the preservation of soft tissues, with sampling of tissues and taphonomic description of the remains.

**Taphonomy**

The body was completely clothed, including boots. The cranium had been displaced and rested on its vertex (upside-down) in the left head end of the coffin. No skin or other external soft tissue adhered to the cranium, and the cranial base and maxillae were fully exposed. At the time of death, eight teeth had been present in the maxillae, but most of these had been displaced postmortem and were later retrieved from the coffin. The mandible had separated from the cranium and was not readily visible.

Based on initial visual assessment and palpation of the clothing, the body seemed skeletonized. The postcranial bones were somewhat disarrayed but, in general, retained anatomic relationship. The degree of articulation could not be fully assessed due to the presence of clothing. Prior to the removal of the clothing, the remains were carefully placed in a body bag and transported to the museum’s computed tomography (CT) scanner. Culture samples were taken, and the external visual examination was completed prior to scanning the body.

After removing the clothes and boots, the remains were further examined for the presence of soft tissue. Segments of skin with some underlying soft tissue were recovered from the left anterior chest region. There was no attachment of this tissue to underlying bony structures. Skin from the chest measured 9 cm by 4 cm at its greatest dimension. An additional ovoid segment of skin measuring 6 cm by 4 cm was present on the posterior portion of the right side of the chest cavity. Two separate segments of skin and some muscle tissue were also present on the posterior portions of both lower legs. The flap of skin from the right leg measured 35 cm by 13 cm and continued over the calcaneus for a distance of 5 cm onto the plantar aspect of the foot. Similar skin and soft tissue were noted over the rear portion of the left lower leg. This piece measured 30 cm by 18 cm and extended over the calcaneus onto the plantar aspect of the foot for a distance of 4 cm. The presence of tall boots undoubtedly aided in the preservation of the lower leg tissue.

In addition to soft tissue, the body was examined for the presence of hair, fingernails, and toenails. No hair or scalp was attached to the skull, although body and head hairs were scattered over the surface of the clothes and throughout the bones. In the thoracic region, hairs were present but difficult to distinguish from the black silk and wool fibers of the deteriorated vest and coat lining. The hair from the head was fine and medium brown in color. Small locks measured up to 6 cm in length with the longest single segment of hair being 10 cm. The body hair was lighter in color than the head hair and was blonde to light brown. Four fingernails were found in the region of the finger bones and ranged in size from 0.9 cm to 1.4 cm. The presence of soft tissues, hair, and nails allowed for the testing for certain toxins and pathogens.

**Microbiology**

As soon as the coffin lid was removed, culture samples were taken under aseptic conditions from the anterior frontal region of the skull, the mid-casket area, the mid-knee region, and from boot level. These specimens were placed in a trans-
port media (remel) and sent overnight to Valley View Regional Hospital Microbiology Laboratory in Oklahoma for processing. A number of microorganisms were grown, which revealed a variety of nonpathogenic soil organisms that included Aeromonas and Pseudomonas. A spore-forming Bacillus subtilis was also grown.

Toxicology

A gas chromatography mass spectrometry study was conducted for the presence of strychnine and arsenic. The material selected for study consisted of brain tissue that was removed from the cranial cavity at the time of autopsy. The specimen was frozen, and approximately 5 g of tissue were submitted to National Medical Services, Willow Grove, Pennsylvania, for processing. Arsenic and strychnine were not detected in the brain tissue.

Radioimmunoassay of Hair

Radioimmunoassay of a hair sample was performed by Valley View Regional Hospital, Ada, Oklahoma (Cartmell et al. 1991). The hair was negative for opiates and cocaine but had cotinine present in levels consistent with tobacco use.

Osteology

Removal of the clothing and remaining body tissues revealed that the skeleton was in excellent condition and externally blackened due to iron sulfide staining. A bluish discoloration was also noted on the anterior surface of the lower femora and upper tibiae due to the presence of vivianite, a hydrated iron phosphate that is occasionally observed on fossils and skeletal remains. The bones were water saturated, and some of the more friable bones such as the ribs and vertebral bodies displayed erosion from contact with the coffin floor. Examination of the remains provided information on sex, age, ancestry, bone and dental pathology, stature and robusticity, and functional morphology.

Sex, Age, and Ancestry

Sex was identified as male, based on the morphology of the skull and pelvis and relatively large joints and teeth. The cranium shows slight development of the supraorbital brow ridges and brow at glabella. The mastoid processes and occipital condyles are moderately large. The nuchal ridge exhibits moderate development with no occipital protuberance present. The palate is relatively large, and the mandible has a slightly squared chin. Male traits in the os coxae include a lack of auricular surface height, absence of pre-auricular sulci, a moderately narrow subpubic angle, and the absence of ventral arcs on the pubic bones. The greater sciatic notches of the os coxae are intermediate in breadth. The postcranial bones exhibit slight development of the muscle attachment sites, although the joint surfaces are large.

An age determination of 33 to 37 years was based on surface changes of the pubic symphysis, auricular surfaces, cranial suture closure, and dental and skeletal pathology. The surfaces of the pubic bones show complete formation of the dorsal and ventral ramparts and rim with slight retention of billowing on the inferior end of the left symphyseal face. The ventral rims are slightly irregular, especially on the right side. Both surfaces display trace porosity, which may be due to slight postmortem erosion of the bone in the wet environment. The sacroiliac (auricular) surfaces display transverse organization with no visible porosity or apical activity. These age-related features of the pelvis are characteristic of a male in his thirties (Lovejoy et al. 1985).

In the cranium, the sagittal and lambdoid sutures are open ectocranially. The coronal suture exhibits closure on the left and right sides at pterion. Endocranially the coronal and sagittal sutures are fully united, but the lambdoid suture is still visible. The posterior palatine suture is nearly united; the incisive sutures are faintly visible.

The postcranial bones show complete epiphyseal union including the sternal epiphyses of the clavicles. The manubrium, sternal body, and xiphoid are fused. Degenerative changes are noted in several postcranial elements, but the condition is slight in severity.

The morphology of the skull, including metric comparison to established reference samples (Ousley and Jantz 1996), identifies this individual as a white male with European ancestry. The cranial shape is mesocranic and the forehead is moderately low and sloping. The mid-face has
a narrow interorbital width, a narrow nasal chamber, and a sharply defined inferior nasal border. In spite of advanced dental pathology, the canine fossae are not readily apparent. The nasal chamber is slightly asymmetrical with the inferior border of the left side slightly lower than the right. The malars are moderately small, and the temporal fossae are deep. The dentition has a slight overbite, as indicated by the pattern of tooth wear and articulation of the mandible with the cranium, but is not prognathic. The mandible is V-shaped and somewhat gracile. The teeth exhibit simple cusp morphology. The ancestry identified by the cranial morphology is consistent with that noted for the femora. The femora are straight with slight posterior curvature of their superior halves.

**Bone Pathology**

The temporo-mandibular joints show remodeling characterized by trace porosity and marked concavity of the temporal fossae. The mandibular condyles have only small areas of joint surface remaining due to pathological erosion. The spinal column exhibits slight degenerative changes including arthritic lipping and Schmorl’s depressions (i.e., vertebral body endplate herniations) in multiple vertebrae. The articular facets of cervical vertebrae three through seven have trace porosity and osteophytes. Thoracic vertebrae one through nine show slight lipping of the articular facet margins and slight porosity of the joint surfaces. The body of the ninth thoracic vertebra has trace lipping of its anterior, inferior margin. More obvious lipping of the anterior body is noted for thoracic vertebrae 10, 11, and 12. The third lumbar vertebra displays a small area of porosity and a small area of osteophyte formation on the joint surfaces of its inferior articular facets. The inferior right articular facet of the fourth lumbar vertebra has slight porosity and surface osteophytes.

Thoracic vertebrae 7 through 11 have Schmorl’s depressions in their vertebral endplates. The seventh thoracic vertebra has a slight circular depression in its inferior endplate with a diameter of 3.0 mm and a depth of approximately 0.8 mm. The eighth thoracic vertebra has a larger, centrally located defect in its inferior endplate. This defect is characterized by a main area with a depressed extension spanning to the left lateral edge of the endplate. The main depression has a transverse diameter of 9 mm and an anterior-posterior (AP) diameter of 5.7 mm. The canal running from the main area is 12.8 mm in length and 2.5 mm wide. The depth of the central defect is 1 mm. The ninth thoracic vertebra exhibits depressions in both its superior and inferior endplates. The superior depression has slight definition and is linear in shape running anterior-posterior. It measures 12.5 mm from the anterior edge to the edge of the neural canal. The inferior defect is much more pronounced and runs from the anterior to the posterior edge of the endplate into the border of the neural canal. The defect measures 21.7 mm in length by 3.6 mm in width and 1.4 mm in depth. This defect shows herniation into the neural canal. The 10th thoracic vertebra has a small Schmorl’s depression in its superior endplate and a larger depression in its inferior surface. The superior defect is too slight to score. The inferior defect is somewhat V-shaped with the point of the V located anteriorly and centrally. The dimensions of the inferior defect are 21 mm transverse by 13 mm AP. The depth of the defect is 3.2 mm. The 11th thoracic vertebra has a well-defined Schmorl’s depression in its inferior endplate that is characterized by two depressed areas. The larger area has herniated into the neural canal and measures 12.2 mm by 4.8 mm with a depth of 2.7 mm. The smaller depression measures 3.1 mm by 6 mm with a depth of 1.5 mm. The 12th thoracic vertebra has a faint depression in its inferior endplate that is too slight to score. The body of the 12th thoracic vertebra also has slight anterior compression resulting in an anterior body height of 24.3 mm and a posterior body height of 31.5 mm. The lipping along the anterior margin of the T12 body is the most severe lipping noted for the vertebral bodies.

Degenerative changes on other bones are minor. The distal joint of the left humerus has trace arthritic lipping on its margin. The head of the right femur has slight lipping along its dorsal margin, and the distal femora have slight lipping along the posterior aspects of the joint margins. The lateral margin of the right patella has slight lipping.
**Dental Pathology**

Eight teeth are present in the maxillae: the left canine and lateral incisor, the right central incisor, lateral incisor, canine, first and second premolars, and third molar. Eight maxillary teeth were lost antemortem, and their sockets have fully remodeled. The missing teeth include the left first, second, and third molars, first and second premolars, and central incisor, and the right first and second molars. Two of the remaining maxillary teeth have carious lesions. The left canine and right second premolar have small areas of decay on their distal interproximal surfaces, specifically at contact facets with adjacent teeth that are no longer present due to antemortem loss. Three maxillary teeth are scored for periodontal abscesses characterized by expansion of the tooth socket and advanced resorption of the alveolar bone. The right central incisor was held in place by gum tissue only, based on advanced socket resorption and porosity. The right lateral incisor also displays periodontal abscessing of the tooth socket, although a greater portion of the distal root is held in place within the socket. The right second premolar has severe cupping (expansion) of the socket and is held in place by only the small apical portion of the root.

A diastema measuring 4.3 mm is present between the roots of the maxillary left canine and lateral incisor. The crown of the left lateral incisor has a facet along its mesial-occlusal edge indicating previous contact with the crown of the central incisor, which would have partially overlapped the lateral incisor crown. The right central and lateral incisors have normal spacing, but the right lateral incisor shows slight supereruption.

Thirteen mandibular teeth are present in their sockets. Three teeth, the left first molar and right first and second molars, were lost antemortem, and their sockets have completely remodeled. Represented teeth include the left second and third molars, first and second premolars, canine, lateral and central incisors, and the right central and lateral incisors, canine, first and second premolars, and third molar. Eight mandibular teeth are carious. The right third molar and second premolar are represented by single tooth roots only due to complete caries destruction of the crowns. The pulp chambers are exposed for these two teeth and the sockets display periapical abscesses. The right first premolar has a small cavity in its distal interproximal crown at its point of contact with the second premolar, which is represented by a root only. The left mandibular second molar has a small interproximal cavity in its distal crown at its contact facet with the third molar. The third molar has a large carious lesion in the mesial interproximal surface of the crown. The decay extends into the root, and the pulp chamber is exposed. Periapical abscessing affected the mandibular left second and third molars. Periodontal abscessing is also noted for the right lateral incisor socket. This tooth does not display decay.

The left central and right lateral incisors show marked supereruption, as the crowns of these teeth project above the other anterior mandibular crowns. The left central incisor projects approximately 4 mm above the occlusal edge of the left lateral incisor. The right lateral incisor projects approximately 3 mm above the occlusal edge of the right central incisor. The remaining anterior mandibular teeth are tightly spaced but do not show crowding.

Calculus buildup is heavy and characterized by coalesced rings surrounding the roots of the teeth. The calculus margin marks the level of resorption for the gingiva. The two supererupted mandibular teeth have particularly heavy, three-dimensional calculus deposition. The level of tooth wear is slight with only blunting of the cusps. A small amount of dentin is exposed on the incisors, canines, and premolars.

**Functional Morphology**

The stature of this individual was approximately 5 ft. 10 in., based on a left femur length of 480 mm (Trotter and Gleser 1958). The skeleton is slightly robust. The right clavicle is slightly larger than the left one and shows greater development of the muscle-attachment sites. There are also slight size differences between the left and right humeri with the right being larger in diameter and longer in length. The ulna and radius are also longer on the right side and have slightly larger shaft diameters, suggesting right-handedness. In addition, the
right scapula exhibits more notable pleating of its blade relative to the left side. There is slight definition of the bone at the attachment sites for the teres muscles on the proximal humeri, and the deltoid tuberosities are slightly defined.

There are sharply defined ridges on the medial and dorsal aspects of the distal femora. The left femur has a distal femoral cortical excavation that measures approximately 16 mm in diameter. The lineae aspera are poorly defined, measuring 8 mm wide and approximately 1 mm high at mid-shaft on the right side. The tibiae have defined soleal lines on the posterior proximal surface. No squatting facets are noted on the distal tibiae.

Several developmental features can be attributed to horseback riding. The left and right acetabulae show slight superior elongation. The attachment sites of the gluteus muscles are defined on the ilia. The femora have large Poirier’s facets, and the attachment ridges of the ilio-femoral ligaments are raised and clearly defined on the proximal femora.

**Stable Isotope Analysis**

A sample of bone was submitted to the Stable Isotope Laboratory at Augustana College for purposes of dietary interpretation. The sample of this study consisted of well-preserved bone, as indicated by a high collagen yield (19.89%), a high percent carbon value (44.45), and a C/N ratio of 3.22. On a scale of 1 to 5 (1 reflecting visibly degraded, poorly preserved bone), the sample received the highest visual rating of 5. The bone yielded a $\delta^{13}$C value of -10.53‰ and a $\delta^{15}$N value of 10.99‰.

**Clothing Analysis**

The individual was wearing a black broadcloth frock coat, indicated by the presence of a waist seam. The coat was of standard construction. A center back seam with a curved back seam on either side created a fitted back. The coat is single-breasted with three buttonholes and an additional buttonhole in the left lapel. The collar and lapel lining show evidence of quilting in a curved pattern, causing the collar to be firm and folded over in a smooth line. The skirt of the coat is 18 in. long and has a vent opening in the center of the back with a turn-over hem and seam on either side. The coat had been fully lined, but the lining had deteriorated and is represented by a mass of thread that is distinct from the thread representing the deteriorated vest. A rectangular hole (2 x 1-3/8 in.) in the right front skirt of the coat near its bottom has been mended with a patch. There is a slit in the left breast of the coat for a pocket, which had come loose. The sleeves remain set in the coat and are of two-part construction. They are slightly shaped at the elbow.

The second button from the bottom is still attached to the coat. The button is metal based and thread covered. It matches three other buttons that were found loose in the coffin. Two metal buttons, once thread covered, are on the back of the coat at the waist seam.

The tailor-made trousers have an inseam of 31 in. and a waist of 32 in. The trouser front has a concealed five-button fly with an additional button at the top of the waistband. Two sew-through buttons with well-preserved yellow gilt are present at the top of the posterior waistband, probably for suspender use. An adjustable enamelled buckle with two strips of fabric in place is present at the back of the trousers. The trousers were constructed with a center back seam and a pieced yoke for fitting, producing a relatively rectangular silhouette. The seam edges are raw, which is not unusual with broadcloth. Buttons were present on the side pockets.

Silk material that had constituted a necktie is still present. It was woven in a square with self stripes near the edges. It had been folded to create a thick band around the neck, with less fabric at the ends to be tied into the bow.

In addition to the tailor-made suit, the man was wearing a pair of good quality leather boots. There are nine lifts in the heel. The widest part of the sole is 3 in. and the length of the boot is 10 in. All seams are hand-stitched. Both boots are missing the piece of leather at the front top of the boot that would have covered the kneecap and was often made of a different leather than the rest of the boot (June Swann 2003, pers. comm.). This piece had been removed, either by preference of the owner or during burial preparations to avoid distorting the trouser leg, which in life would have been tucked in the top. The toe end is slightly rounded with a high toe spring and a snug fit at the waist.
Thomas A. Crist

The Good, the Bad, and the Ugly: Bioarchaeology and the Modern Gun Culture Debate

ABSTRACT

In his controversial book *Arming America: The Origins of a National Gun Culture*, historian Michael A. Bellesiles argued that personal gun ownership was uncommon prior to 1850. His book triggered an intense re-examination of the American gun culture. A subsequent investigation into his alleged misuse of antebellum probate records to support his thesis resulted in his forfeiture of the prestigious Bancroft Prize and the loss of his position at Emory University. Historical archaeologists can contribute to the debate on the popularity of guns in early America armed with objective data on the frequency and distribution of gun-related artifacts. Analysis of historic period human remains provides another dimension to the modern gun-culture debate through documentation of the prevalence of gunshot wounds, including those among minority groups whose rates of firearm trauma were generally unreported in official statistics before the 1930s. By accurately recognizing and systematically recording gunshot wounds among historical population samples, bioarchaeologists are uniquely positioned to report the actual frequency and, in many cases, the contexts within which such wounds occurred in the past.

Introduction

Archaeology is a rigorous discipline that provides data from past material culture through which questions of history can be addressed effectively. From the fields at Little Big Horn to the underwater grave of the famous submarine CSS *H.L. Hunley*, archaeologists employ standardized techniques of recovery and analysis to reconstruct historical events more accurately than is possible using only documentary evidence. While the concept of “objective” historical data and the ability to document a knowable “truth” may be debated based on one’s theoretical perspective, there is no doubt that the archaeological record provides information that both complements and challenges documentary data, the primary and often limited resource of the historian. Indeed, in many cases the archaeological record “yields information and generates questions not available in the documentary sources” (Handler and Lange 1978:216). Unfortunately, to their detriment the vast majority of historians fail to adequately incorporate archaeological data into their research.

Much of the value of archaeology lies in its ability to elicit interpretations of modern society through the contextual lens of behavioral patterns in the past. This is a general theme among archaeologists, elegantly summarized by Brian Molyneaux (1994:12): “if there is going to be a shared vision of the future, there must be a recognition of the multiple pasts that have determined the present.” Foremost among the current social and, not incidentally, public health issues faced in the United States is the high incidence of violence committed with firearms. This particular issue is closely related to personal gun ownership and gun control, two inter-connected topics of considerable controversy.

In her book *The Way We Never Were: American Families and the Nostalgia Trap*, Stephanie Coontz (2000:xiii) writes, “Nostalgia for a safer, more placid past fosters historical amnesia ... deforming our understanding of what is and is not new in contemporary violence.” Archaeologists address the desire for a more precise understanding of the past through systematic and standardized analyses of material culture interpreted within myriad historical contexts from battlefields to domestic sites. Bioarchaeologists, who study human remains from archaeological contexts, assist in this effort by generating data on the actual prevalence of trauma among people from a wide range of temporal, geographic, and socioeconomic spheres. George Gill (1994:159) emphasizes this point in his review of skeletal injuries among pioneers of the American West by noting, “As a means of documenting violent episodes, human osteology is an excellent tool.” While offering only a glimpse of the violence that occurred throughout historical America, these data contribute in a unique way to the current debate about gun control, a controversy whose two sides selectively claim historical precedents to support their positions.

Permission to reprint required.
Saga of the Discredited Historian

For historians studying violence and what is termed the “American gun culture,” looking at the past has placed many of them directly in the firing line of today’s highly politicized debate on Second Amendment rights and gun control. There are basically two camps in the American gun culture: the gun-rights group and the gun-control group, both of which compete with each other for political power, financial resources, and popular support (Utter and True 2000). Nowhere is this struggle more evident than in the disheartening tale of former Emory University history professor Michael A. Bellesiles (pronounced “buh-leale”).

In fall 2000, Bellesiles published *Arming America: The Origins of a National Gun Culture*. Awarded Columbia University’s Bancroft Prize in 2001—the most prestigious award in American history writing—Bellesiles’s main premise was that, prior to the Civil War, individual gun ownership in America was rare, and the tradition of an American gun culture is in fact a modern invention. In the introduction to his book Bellesiles (2000:5) summarized his contentious findings:

This book argues that gun ownership was exceptional in the seventeenth, eighteenth, and early nineteenth centuries, even on the frontier, and that guns became a common commodity only with the industrialization of the mid-nineteenth century, with ownership concentrated in urban areas ... The industrialization of the arms industry allowed the [US] government to move toward its goal [of arming its citizens] with ever-increasing speed, though in the face of residual public indifference and even resistance.

Thus, the book’s main thesis was that because primary records indicate that there were relatively few guns in use in America prior to the 1860s, history supported modern gun-control advocates.

Bellesiles’s position was neither groundbreaking nor revolutionary. For instance, in his authoritative study of homicide, *Murder in America: A History*, Roger Lane (1997:344)—who won the Bancroft Prize in 1987—noted, “Every government except Quaker Pennsylvania at least theoretically required that able-bodied free men should own [guns], as members of the militia. ... While in practice many could not afford or use them, large numbers could and did; colonial history is full not only of war but of riot, rout, tumult, and insurrection among armed rebels.” Homicide rates in the colonies remained lower than in contemporaneous England, and most murders were not committed with firearms. This remained the case throughout the country until the late 1830s. “Whatever was happening out on the frontiers or down on the plantations, it appears in fact that it was not until the 1840s and 1850s [after the mass introduction of revolvers] that the American homicide rates in more settled areas, such as New York City, began to soar above those in comparable English places” (Lane 1997:344).

What was new in Bellesiles’s work was that he based his conclusions on what was initially praised as his innovative use of 18th- and 19th-century probate records from 40 counties that he grouped into four major regions of the country (northern urban, northern rural, south, and western frontier). Regarding the impetus for the book Bellesiles (2000:445) writes:

While studying county probate records (inventories of property after a death) for a project on the legal and economic evolution of the early American frontier, I was puzzled by the absence of something that I assumed would be found in every record: guns. ... That was the beginning of this project, a ten-year search for “a word that isn’t there.”

His estimates of the proportion of Americans who possessed guns in early America ranged from 15% in 1790 to 21% in 1830 (Bellesiles 2000:445), considerably lower than figures he cites from previous gun culture researchers.

Bellesiles’s conclusions reverberated through the gun-rights community and re-ignited the debate regarding the founding fathers’ intentions when they wrote the Second Amendment to the Constitution guaranteeing private citizens the right to keep and bear arms. Indeed, in an article defending his book written for the *Organization of American Historians Newsletter*, Bellesiles (2001) himself reports receiving a flood of hateful, threatening emails, telephone calls, and faxes as well as disparaging remarks from actor Charlton Heston, former president of the National Rifle Association.

As controversial publications commonly do, *Arming America* drew both praise and scorn. In his review for the *Journal of American History*,...

Shortly after its release, however, a number of historians focused on Bellesiles’s use and analyses of the probate records, some of which could not be located in the archives that Bellesiles stated he had visited. The historians found discrepancies that they later charged had represented data falsified by Bellesiles to support his predetermined results and create an antigun vision of the past. When pressed regarding the collection and analyses of his primary data, Bellesiles claimed that none of the data were computerized and that his handwritten notes had been destroyed when his university office was flooded (Seckora 2001a; 2001b). He also could not identify repositories in which he claimed to have conducted research with primary documents and insisted that he had reviewed records in archives that subsequently proved nonexistent (Seckora 2002).

These explanations regarding five paragraphs on probate records out of 444 pages of text led Emory University in February 2002 to take the unprecedented step of empowering two different investigative committees to undertake inquiries into the allegations of scholarly fraud and research misconduct lodged against Bellesiles. The external committee determined that, in his use of the probate records, Bellesiles was guilty of substandard research methodology and willful misrepresentation of specific evidence. Neither committee was charged with investigating the other material in the book, but other historians claim to have found numerous misrepresentations and statistical errors. (An academic appraisal of the claims and implications of Arming America by four independent historians and Bellesiles’s reply is the topic of the Forum on Historians and Guns in William and Mary Quarterly 59[1]:203–268.) In September 2002, Bellesiles appealed the committee’s conclusions but under intense pressure, he resigned his position at Emory at the end of October, citing the hostile work environment (de la Merced 2002). On 7 December 2002, the Columbia University Board of Trustees voted to revoke Bellesiles’s Bancroft Prize, finding that he had “violated basic norms of acceptable scholarship and the high standards expected of Bancroft Prize winners” (Columbia News 2002). The publisher of Arming America, Alfred A. Knopf, subsequently announced that it would stop selling the book and terminate its contract with Bellesiles.

The initial reviews of Arming America all applauded Bellesiles’s use of probate records to explore the prevalence of personal gun ownership by Americans in the past. Probate records have long been an important resource for historical archaeologists as well as many historians; witness the title of arguably the field’s most famous book, In Small Things Forgotten, excerpted from a common notation among historical probate records (Deetz 1977). In fact, for her critical discussion of Bellesiles’s misinterpretation of probate records Gloria L. Main (2002) paid homage to James Deetz’s book by titling her paper “Many Things Forgotten: The Use of Probate Records in Arming America.” A thorough review of Arming America’s extensive bibliography and acknowledgments, however, indicates that Bellesiles’s methodological creativity did not extend to consulting the archaeological record for information regarding gun ownership and use during the historic period. Contrast this approach with M. L. Brown’s (1980) book Firearms in Colonial America: The Impact on History and Technology, 1492–1792, which includes numerous references to archaeological data, including John L. Cotter’s work at Jamestown. A survey of gun-related artifacts and their distribution across various types of sites as well as input from historical archaeologists may have supplied Bellesiles with data that supported the conclusions he had based on the probate records.

Data on the frequency and distribution of gun-related artifacts in the archaeological record certainly offer the potential to contribute in an important way to the debate regarding the prevalence of guns during the historic period. The bioarchaeological record does as well. Bioarchaeology is the branch of anthropology that “emphasizes the human biological component of the archaeological record” (Larsen 1987: 340). Analysis and documentation of historic
period human remains provides a fresh dimension to the gun culture debate by revealing not the prevalence of guns but of gunshot wounds, lesions that are clearly identifiable and distinguishable from other skeletal defects. These osteological data may then be applied to support or repudiate Bellesiles’s thesis and those of other gun culture historians regarding the true nature of gun-related violence in historical America. Of course, the possession of firearms and the actual use of firearms are not necessarily equivalent. Bioarchaeologists, however, are uniquely positioned to report the actual frequency and, in many cases, the contexts within which such firearms use occurred. Systematically compiling this information not only assists investigators with supporting or refuting the historical record but also assists them with accepting or rejecting historians’ interpretations of that record. It is to this latter effort that bioarchaeology may make the greatest contributions by providing tangible skeletal evidence that is less susceptible to misinterpretation or, worse, falsification by an investigator.

Recognizing Gunshot Wounds in Dry Bone

Firearm projectiles produce distinctive wounds in bone that are distinguishable from postmortem damage and other types of trauma. Depending on the caliber, construction, velocity, and trajectory of the ammunition, projectile impacts result in penetration, fractures, and displacement of bone fragments. Historic period handguns and rifles ejected one bullet at a time; shotguns propelled multiple lead or steel pellets when fired. Armed with a basic understanding of ballistics, forensic anthropologists analyze projectile wounds in dry bone to determine the caliber (diameter) of the bullet, its direction of fire and trajectory inside the body, and the sequence of wounds. The following description of the effects of projectiles on bone is largely drawn from the work of Hugh Berryman and Steven Symes (1998:344–351), Vincent DiMaio (1998), and Steven Byers (2002:274–293).

Bullet wounds to the cranium are characterized by beveling and fracture lines. When a bullet perforates a bone, it deforms, causing an exit hole that is larger than the defect at the entrance point (Figure 1). The resulting funnel effect or “cone of force,” which is also generated when a nondeforming projectile enters bone, creates beveling of the wound. Since the bones of the cranial vault comprise flat, thin inner and outer tables separated by the diploic space, entrance wounds are characterized by sharp round or oval defects in the exterior (ectocranial) surface and beveling of the interior (endocranial) surface. In many cases, the size of the entrance wound corresponds with the caliber of the projectile that caused it (Berryman et al. 1995). In contrast, exit wounds are usually much larger than entrance wounds, with beveling of the ectocranial surface that results as the projectile or its fragments pass through the bone, removing portions of the outer table as it exits. Both types of projectile-related cranial defects may be distinguished from damage caused by burial or metal probes and augers by comparing the colors of the exterior and interior bone surfaces; postmortem breaks in bone

FIGURE 1. Fracture lines and beveling typical of a .45 caliber gunshot wound to the cranium. Note entrance wound above right orbit and exit wound in right parietal. (Specimen No. 10291 from Army Medical Museum [now Armed Forces Institute of Pathology]; photo from LaGarde 1916:185.)
are characterized by differential weathering of the surfaces and consequent color differences between the intact and broken edges (Sauer 1998:325).

Cranial vault bones struck by projectiles also display distinctive fracture patterns. Radiating fractures move outward from the point of impact and follow areas of weakness in the cranial vault (Figure 1). These fractures travel through the cranial vault until they encounter a suture or another fracture line, where they either stop or follow the line for a short distance until they continue in their original direction. Concentric fractures are caused by higher velocity projectiles and appear as circles or parts of an arc at various intervals from the point of impact. These fractures terminate when they encounter sutures or other fracture lines. Both types of fracture lines occur in association with entrance and exit wounds.

Long bones struck by bullets typically shatter upon impact, although low-velocity projectiles may lodge in the bone without causing significant fractures or bone loss. So-called “butterfly” fractures occur around the impact site and may extend both superiorly and inferiorly along the long axis of the shaft (Figure 2). These fractures can be distinguished from the effects of weathering, which results in mosaic or longitudinal cracks along the bone’s surface as it warps due to dehydration.

Pellets from shotgun shells spread out as they approach the victim, producing multiple small indentations or perforations in the bones they strike. Due to this fact of ballistics, the range of fire can be estimated based on the maximum diameter of the dispersal pattern. Although scavenging carnivores may produce puncture marks in bone that are similar in appearance to the perforations from shotgun pellets, furrows or U-shaped grooves usually accompany animal gnawing.

In the absence of a clearly associated projectile or its fragments, the most definitive method of determining whether a bone lesion represents a gunshot wound is radiographic analysis. Fragments of the projectile are often embedded along the edges of the impact or exit wounds as well as in the bony tissue that surrounds these defects and appear opaque in radiographs. Additional projectile fragments may be embedded opposite

FIGURE 2. Typical “butterfly” fracture of tibial diaphysis caused by a .30 caliber bullet. (Cadaver specimen from Army Medical School collection; photo from LaGarde 1916:47.)
the entry wound in the cranial vault and thorax. Passing the remains under a fluoroscope often reveals these fragments without the need for more extensive radiographs.

**Historical Context**

The first recorded importation of firearms to the New World was by Christopher Columbus, who brought 100 arquebuses (harquebuses in French, referring to small matchlock muskets) when he returned to the La Navidad settlement on Hispaniola in 1493 (Lavin 1965:43; Brown 1980:35). In March 1495 the Spanish colonists used these weapons in what became the first major engagement between Europeans and Native Americans, devastating the local Tainos prior to an anticipated attack on the Spanish settlement (Brown 1980:36). The French likewise employed the arquebus against their Native American enemies. In one of the earliest documented uses of a gun by a European in the New World, Samuel de Champlain reported in 1613 that, on 30 July 1609, he fatally shot three Mohawk chiefs with his arquebus during an encounter along the shore of the lake that would later be named in his honor (Champlain 1922:94–107). Brown (1980:91) notes, “Champlain’s lethal volley cost France dearly in the ensuing struggle for supremacy in North America, for thereafter the Five Nations comprising the powerful Iroquoian Confederacy displayed an implacable, nearly unremitting hatred of the French” and consequently became allies of the British. The matchlock arquebus emerged as a martial weapon in both Europe and the New World during the first quarter of the 16th century; “thereafter the role of firearms continuously escalated in domestic and military affairs. ... as the Renaissance blossomed, firearms technology advanced at an unprecedented rate” (Brown 1980:27).

By the 18th century in England and throughout most of Europe, only the elite were legally permitted to own firearms, which they generally used for hunting game (Lane 1997:41). In contrast, from very early in its colonial history the British established armed civilian militias and “made owning a musket a civic duty” (Lane 1997:41), recognizing the mortal threats to their colonists posed by the French, Spaniards, and Native Americans as well as by bears and wolves. Nonetheless, early guns were bulky, expensive, inaccurate, and slow loading—all of which combined to limit the general popularity of guns. The proportion of the American population that owned guns during the colonial period remains a matter of contentious debate, one that lies at the very heart of the Bellesiles controversy.

Samuel Colt’s introduction of a revolving handgun in the early 1830s dramatically altered the nature of firearms, interpersonal violence, and gun ownership in the United States. Known as the “great equalizer,” this gun enabled a person to preload six shots into a single, relatively small weapon that required no priming, thereby significantly increasing its lethality over the single-shot guns that it ultimately replaced (Edwards 1957; Haven and Belden 1988). The deadly efficiency of Colt’s six-shooter was reflected in the common 19th-century expression, “there is more law in a Colt six-gun than in all the law books.”

Samuel Colt was a master promoter who began his career in 1832 as a traveling salesman hawking nitrous oxide (laughing gas) throughout the country (Hosley 1996). There is no question about the impact of Colt’s guns: between 1836 and his death in 1862, Colt’s firms sold almost one million firearms. During this period, gangs in the eastern cities began to replace their knives, brass knuckles, and clubs with revolvers, which in turn triggered more pervasive gun ownership among the middle and upper classes who sought personal protection from increasing street crime, whether real or perceived. Homicide rates likewise reflect the popularity of the new type of gun: for example, in Philadelphia about 15% of fatalities among the city’s population between 1839 and 1852 resulted from firearms (Lane 1997:117). This figure rose to 25% between 1853 and 1859 (Lane 1997:117). A truly striking rise in firearms deaths ensued over the next six decades: by the mid-1920s about 71% of all homicide deaths in the United States resulted from gunshot wounds, far greater than the 25% of deaths over the entire 19th century (Lane 1997:229).

As firearm deaths became more common through the late-19th century, a geographical dichotomy in the choice of personal gun ownership arose. Rifles and shotguns, primarily used as tools, became more common in the West...
and revolvers predominated in the East. “The surging urban prosperity of the period made cheap pistols more affordable than ever, and the publicity given crime news [by the penny press] added to the fear” of street crime to the extent that “the guns involved in city shootings were almost always revolvers” (Lane 1997:230). By the 1880s, “the price of a revolver had fallen to about two dollars, or about two days’ pay” for many common workers (Lane 1986:139).

It was not until the late 1870s that revolvers began to infiltrate the western territories in large numbers. In discussing the lawlessness and violence that pervaded much of the New Mexico Territory after the Civil War, William Keleher (1957:15-16) writes,

> Two things above all others seemingly contributed to the violence of the day: the over-generous consumption of hard liquor, and the widespread practice of too hastily resorting to the use of improved deadly weapons. ... Liquor and guns ordinarily were sold in the same establishment. ... From and after 1870, any man carrying a gun in most parts of the Territory ... was obliged to arm himself with a new style weapon.

Demographic and economic factors also fostered an environment in which excessive violence became common in the last quarter of the 19th century. In his groundbreaking study of violence and the treatment of racial minorities by the criminal justice systems of the historical West, Clare McKanna (1997:168–173) links high homicide rates between 1880 and 1920 in three diverse western counties (Douglas County, Nebraska; Las Animas County, Colorado; and Gila County, Arizona) with social instability, noting that among the factors that produced almost daily violence were rapid population growth and high population mobility, ethnic diversity, racial hostility, the growing preponderance of concealed weapons, and extensive alcohol consumption. McKanna’s data, drawn from census records and coroners’ inquests, demonstrate that violence in the western frontier was daily and pervasive, not episodic as commonly perceived by other historians and the public alike.

For more than a century, perceptions of western violence have inaccurately emphasized the hired gunfighter, especially as portrayed through American folklore and propagated by the movie industry and television westerns. From Jesse James to Billy the Kid, outlaws have been glorified to the point that historical accuracy regarding their deeds is far outweighed by their myths (Tatum 1982; Courtwright 1996; Utter and True 2000). Regarding the popular notion of western gunslingers, Lane (1997:171) regrets that “it is a historian’s unpleasant duty to inform readers steeped in Hollywood legend that nowhere in the Wild West, not ever, did any two cowboys or anyone else stand in the middle of a street, revolvers strapped to their sides, and challenge each other to a fatal ‘quick draw’ contest.”

**Gunshot Victims in the Archaeological Record**

It is within this historical context of more than 400 years of firearms use that gunshot victims are found in the archaeological record. A review of more than 50 cultural resources management reports and bioarchaeological articles in journals and edited volumes reveals that most gunshot victims found to date in archaeological contexts died after 1850 (Table 1). With one exception (Novak and Kopp 2003:98–99), all of the victims were adults. The vast majority was of European descent, although African American gunshot victims have been identified at sites in New York City (one woman), Philadelphia (two men), New Orleans (one man), and Wyoming (one man). These results are skewed in part due to the disproportionate number of postbellum burials that have been excavated in the western United States but also reflect documented trends in the advent and distribution of reliable, mass-produced handguns through the last half of the 19th century.

Although Bellesiles focused primarily on personal gun ownership and nonbattlefield fatalities, with some undocumented burials it is impossible to distinguish the victims of warfare from those whose deaths resulted from interpersonal violence. Such is the case regarding the earliest osteological evidence of a gunshot wound in the American colonies. Discovered during excavations in 1996 within the James Fort footprint at Jamestown, Virginia, the remains of a European man (designated JR102C) were found with an unhealed fracture of the proximal right tibia, above which was embedded an intact lead ball and 21 fragments of another lead shot (Kelso et al. 1997:1–4). Interred in a coffin near the
southeast bulwark of the stockaded triangular enclosure erected by the settlers in June 1607, this 17–25-year-old man may have been one of the “gentlemen” noted in the colony’s records as having died that year. A very entertaining scenario that elegantly integrates historical and forensic evidence (Kelso et al. 1998:1–24) suggests that another settler may have murdered the young man in a political dispute over leadership of the fledging colony. Not only does this case

<table>
<thead>
<tr>
<th>Name/Burial ID</th>
<th>Location</th>
<th>Race/Sex, Age</th>
<th>Date of Death</th>
<th>Gunshot Wounds</th>
</tr>
</thead>
<tbody>
<tr>
<td>BNHP 07</td>
<td>Boston, MA</td>
<td>WM, 25–30</td>
<td>Unknown (1775?)</td>
<td>Cranium (?)</td>
</tr>
<tr>
<td>Calvin Luther, Jr.</td>
<td>Johnston, RI</td>
<td>WM, 53</td>
<td>1875</td>
<td>Right ribs 2 and 3</td>
</tr>
<tr>
<td><strong>Mid-Atlantic</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Burial 25</td>
<td>Manhattan, NY</td>
<td>BF, 18–25</td>
<td>ca 1630s–1796</td>
<td>Thorax</td>
</tr>
<tr>
<td>Burial 1 (Theodosius Bartow?)</td>
<td>Shrewsbury, NJ</td>
<td>WM, 50–55</td>
<td>1720–1769 (1746?)</td>
<td>Cranium</td>
</tr>
<tr>
<td>Burial 65</td>
<td>Philadelphia, PA</td>
<td>WM, 45–55</td>
<td>1750–1799</td>
<td>Cranium</td>
</tr>
<tr>
<td>Burial 13</td>
<td>Philadelphia, PA</td>
<td>BM, 55–59</td>
<td>ca. 1810–1822</td>
<td>Right scapula</td>
</tr>
<tr>
<td>Burial 65 (FABC)</td>
<td>Philadelphia, PA</td>
<td>BM, 60–64</td>
<td>ca. 1810–1822</td>
<td>Right radius/ulna</td>
</tr>
<tr>
<td><strong>South</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>JR102C</td>
<td>Jamestown, VA</td>
<td>WM, 17–25</td>
<td>1607?</td>
<td>Right tibia</td>
</tr>
<tr>
<td>56a</td>
<td>New Orleans, LA</td>
<td>BM, 35–45</td>
<td>1853–1929</td>
<td>Thoracic vertebra</td>
</tr>
<tr>
<td>134b</td>
<td>New Orleans, LA</td>
<td>WM, 30–35</td>
<td>1853–1929</td>
<td>Right femur</td>
</tr>
<tr>
<td>John Yarbrough</td>
<td>Calliham, TX</td>
<td>WM, 88</td>
<td>1862</td>
<td>Not reported</td>
</tr>
<tr>
<td>Martin Taylor</td>
<td>Calliham, TX</td>
<td>WM, 27</td>
<td>1869</td>
<td>Not observable</td>
</tr>
<tr>
<td>William Morris</td>
<td>Calliham, TX</td>
<td>WM, 67</td>
<td>1869</td>
<td>Not observable</td>
</tr>
<tr>
<td><strong>West</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rock Ranch Burial 1</td>
<td>Torrington, WY</td>
<td>BM, 24–30</td>
<td>ca. 1850–1860</td>
<td>Cranium and lower back</td>
</tr>
<tr>
<td>Bordeaux Burial 15</td>
<td>Lingle, WY</td>
<td>WM, 31–37</td>
<td>1869/1870</td>
<td>Left femur and cranium</td>
</tr>
<tr>
<td>Individual 1</td>
<td>Mtn. Meadows, UT</td>
<td>WM, 20–34</td>
<td>1857</td>
<td>Cranium</td>
</tr>
<tr>
<td>Individual 6</td>
<td>Mtn. Meadows, UT</td>
<td>Ind., 10–15</td>
<td>1857</td>
<td>Cranium</td>
</tr>
<tr>
<td>Individual 7</td>
<td>Mtn. Meadows, UT</td>
<td>WM, 30–39</td>
<td>1857</td>
<td>Cranium</td>
</tr>
<tr>
<td>Individual 8</td>
<td>Mtn. Meadows, UT</td>
<td>WM, 20–34</td>
<td>1857</td>
<td>Cranium</td>
</tr>
<tr>
<td>Individual 9</td>
<td>Mtn. Meadows, UT</td>
<td>WM, 29–34</td>
<td>1857</td>
<td>Cranium</td>
</tr>
<tr>
<td>Individual 12</td>
<td>Mtn. Meadows, UT</td>
<td>WM, 18–24</td>
<td>1857</td>
<td>Cranium</td>
</tr>
<tr>
<td>Individual 17</td>
<td>Mtn. Meadows, UT</td>
<td>WM, 20–34</td>
<td>1857</td>
<td>Cranium</td>
</tr>
<tr>
<td>Jesse James</td>
<td>Kearney, MO</td>
<td>WM, 34</td>
<td>1882</td>
<td>Cranium</td>
</tr>
<tr>
<td>Elmer J. McCurdy</td>
<td>Pawhuska, OK</td>
<td>WM, 31</td>
<td>1911</td>
<td>Thorax</td>
</tr>
<tr>
<td>Archibald Stewart, Sr.</td>
<td>Las Vegas, NV</td>
<td>WM, 49</td>
<td>1884</td>
<td>Cranium</td>
</tr>
<tr>
<td>William Kiel</td>
<td>Las Vegas, NV</td>
<td>WM, 51</td>
<td>1900</td>
<td>Left radius/ulna and cranium</td>
</tr>
<tr>
<td>Edwin Kiel</td>
<td>Las Vegas, NV</td>
<td>WM, 53</td>
<td>1900</td>
<td>Cranium</td>
</tr>
<tr>
<td>William Johnson (Burial 10)</td>
<td>Seven Rivers, NM</td>
<td>WM, 36–45</td>
<td>1878</td>
<td>Cranium and mandible</td>
</tr>
<tr>
<td>William Johnson (Burial 16)</td>
<td>Seven Rivers, NM</td>
<td>WM, 20</td>
<td>1882</td>
<td>Left scapula</td>
</tr>
<tr>
<td>James Gordon (Burial 16)</td>
<td>Seven Rivers, NM</td>
<td>WM, 20</td>
<td>1882</td>
<td>Left scapula</td>
</tr>
<tr>
<td>Burial 17 (Ike Teeters?)</td>
<td>Seven Rivers, NM</td>
<td>WM, 17–22</td>
<td>1878/1879?</td>
<td>Cranium</td>
</tr>
<tr>
<td>John Northern (Burial 20)</td>
<td>Seven Rivers, NM</td>
<td>WM, 27</td>
<td>1887</td>
<td>Right scapula</td>
</tr>
<tr>
<td>Burial 35 (Jefferson Kent?)</td>
<td>Seven Rivers, NM</td>
<td>WM, 36–45</td>
<td>1890?</td>
<td>Sternum</td>
</tr>
<tr>
<td>Burial 41 (Thomas Walker?)</td>
<td>Seven Rivers, NM</td>
<td>WM, 18–45</td>
<td>1879?</td>
<td>Not observable</td>
</tr>
<tr>
<td>Burial 42 (James Barnes?)</td>
<td>Seven Rivers, NM</td>
<td>WM, 31–35</td>
<td>1893?</td>
<td>Thorax</td>
</tr>
<tr>
<td>Burial 47 (Zachary Light?)</td>
<td>Seven Rivers, NM</td>
<td>WM, 23–30</td>
<td>1890/1891?</td>
<td>Cranium</td>
</tr>
</tbody>
</table>
possibly represent the first documented European murder in the New World, but it also set the stage for the South to become the most murderous part of the country, a dubious title gained early in the 19th century that holds true even today (Lane 1997:149, 235, 350).

Another individual who may have been buried during the 17th century also represents an intriguing historical mystery. An important early urban colonial site, the African Burial Ground in Lower Manhattan is best known for the controversy arising from its excavation between 1991 and 1993 (Harrington 1993; LaRoche and Blakey 1997; Mack and Blakey 2004). Although not as well publicized, in 1991 archaeologists at the site discovered the only African American woman with a gunshot wound from an historic period burial ground thus far reported in the literature.

In use between the middle 1600s and 1796, the African Burial Ground contains the remains of thousands of individuals, 427 of whom were disinterred prior to construction of a federal office building (Blakey 1998; Blakey and Rankin-Hill 2004). Among this group was Burial 25, a woman of African descent in her early 20s discovered “with a musket ball near her ribs” (Blakey 1998:56). Interpreting the woman’s remains within a specific context of colonial African American resistance to enslavement, the circumstances surrounding the apparent gunshot wound were described by Michael Blakey (1998:56) as follows:

... she had been shot in the back, with the projectile having entered through her left scapula. The backs of her ribs are fractured as though by the rambling projectile. Burial #25 has multiple blunt force fractures of her lower face. She has a diagonal fracture of her lower right arm which occurred while the arm was being twisted. None of the fractures had healed and were doubtlessly related to the cause of her death. There is much that we will never know about her traumatic story, but the story that can be pieced together is one of resistance to a person or persons with access to firearms.

Mark Mack and Blakey (2004:15–16) basically repeat this description, adding that “Remodeled bone at the margins of the fracture [of the right radius] indicates that she might have lived for several days following the assault.” The official project report (Blakey and Rankin-Hill 2004: 467–470) also describes her left radius as shattered and her right radius as presenting a “spiral green bone fracture of the distal metaphysis.” If their scenario is indeed accurate, the woman subsequently known as Burial 25 represents a powerful symbol of African American resistance and perseverance, rightfully making her a figure of national significance. As with other aspects of the African Burial Ground project, however, questions regarding the accuracy of these speculative interpretations have arisen.

While it is entirely likely that the presence of the lead ball among the woman’s ribs indicates a gunshot wound, unlike other cases reported in this paper the osteological evidence is not conclusive. No description of the ball found with Burial 25’s remains has yet been published. It appears that the field image taken when the remains were first exposed is remarkably free of any deformations caused by the impacts on the bones described by the investigators (Figure 3). No entrance wounds apparently were present among the bones, and none of the reported skeletal damage can be attributed specifically to a projectile wound. Unfortunately, radiographs of Burial 25’s remains were not obtained, and her remains were reburied in October 2003. Although Blakey (1998:56) writes, “Comparisons were made with musket wounds at the United States Armed Forces Institute of Pathology,” no discussion of the results of this comparative process has been published.
The in-situ field photograph of the individual provides equivocal evidence that the ball’s location was the result of a gunshot wound (Figure 3). As depicted in this image of record, damage to the facial bones was very similar to that exhibited by most of the other individuals found in the burial ground (according to Vicki Wedel [2004] only 42 of the 427 burials included intact crania) and may represent postmortem crushing rather than perimortem trauma. This is also true of the reported lesions of the radii and ribs. Without the results of radiographic and ballistics analyses, it is difficult to determine the true origins of the damage to the Burial 25’s bones. Additional, corroborative information is needed to irrefutably exclude other explanations for the presence of the lead ball among Burial 25’s remains, so important as she is to both African American heritage and the history of firearms use in colonial America.

Two other 18th-century individuals may represent the earliest gunshot victims found to date in New Jersey and Pennsylvania, respectively. Christ Episcopal Church in Shrewsbury, New Jersey, was built in 1769 over a burial ground previously used by the vestry between ca. 1720 and 1732. In 1997, installation of new mechanical systems in the church’s basement revealed the partially disturbed remains of at least five individuals, including Burial 1—a white male about 50 years old with a gunshot wound to the cranium that undoubtedly had been fatal (Crist 1998:8–9). The ball had entered his skull just anterior to the left ear, producing a classic entrance wound in the left temporal, and had exited through the back of his head, creating a large defect through the occipital and right parietal (Figure 4). No associated projectile was recovered, but the bloodstain from the classic exit wound was clearly visible on the endocranial surface of the occipital, even after more than 200 years in the ground (Figure 5). Church records did not provide any information regarding this individual’s identity or the circumstances of his death, but a clue to his name was found in the floor of the church above him where three gravestones had been built into the floor in 1769. One of the stones memorialized Theodosius Bartow who had died in 1746 at the age of 54. The position of the entrance wound does not allow a conclusive determination to be made regarding whether the man’s death resulted from a homicide or suicide, although individuals who committed suicide during the colonial period were typically barred from burial in the church’s graveyard. If the remains were indeed Bartow’s, he represents one of New Jersey’s earliest gunshot victims, regardless of whose finger pulled the trigger.

Also dating from the 18th century, excavation of the former Second Presbyterian Church Burial Ground at Independence National Historical Park in Philadelphia, Pennsylvania, revealed one individual, a white male (age 45–55) who presented a fatal gunshot wound in the middle of his forehead, just above his eyes (Figures 6 and 7). Located two blocks south of Independence Hall and excavated in 2000 prior
to construction of the National Constitution Center, this burial ground was in use between 1750 and ca. 1864. The section in which the gunshot victim was located predates ca. 1799 when Cherry Street was laid out over his grave and those of 40 other individuals interred in the rear of the burial ground (Crist et al. 1999:14). A deformed lead ball was recovered from within the cranium, and additional fragments were embedded in the endocranial surface of his occipital, having passed through his frontal and then fragmenting within his brain. This individual presented no other evidence of trauma. Similar to the gunshot victim found beneath Christ Episcopal Church, this anonymous man represents either one of the American colonies’ earliest homicides, suicides, or battlefield deaths.

Two other individuals with gunshot wounds, both from same burial ground, also have been found in Philadelphia. Used between ca. 1810 and 1822 and subsequently sealed beneath row houses and later a street, the Tenth Street First African Baptist Church Burial Ground was excavated in 1990 and revealed the remains of 89 individuals, including 56 adults (Crist et al. 1996, 1997). The church had split into two congregations in 1816 over a number of issues, including abolition and the congregation’s pastorate. According to subsequent testimony given in front of the Philadelphia Baptist Association, a Sunday service in 1816 was violently disrupted when a fight broke out among church members, culminating in gunfire that injured at least one man in the thigh (Crist et al. 1996:24).

Two of the 18 African American men from the burial ground presented healed gunshot wounds, neither of which had been immediately fatal (Crist et al. 1997:37–38). Burial 13 was a man (aged 55–59) who exhibited a large defect in the body of his right scapula that in radiographs presented numerous metal fragments embedded within the surrounding bone, which had healed around them. Several of his right ribs and his right radius also presented healed fractures, which likely occurred in association with the injury to his scapula. No metal fragments were observed in radiographs among these other lesions. The second individual (Burial 65), a male who was 60 to 64 years old at death, exhibited a healed fracture of his right radius and ulna with extensive ossification of the interosseous membrane that held the two bones in opposition to each other (Figure 8). Radiographs revealed metal fragments embedded in both bones as well as in the ossified ligament between them (Crist et al. 1997:37–38). It is possible that these men were shot during the church melee in 1816, although neither presented osteological evidence of a gunshot wound to the lower limbs.

Another African American man who exhibited a gunshot wound was discovered during excavations of the Charity Hospital/Cypress Grove II...
Cemetery in New Orleans (Owsley et al. 1990). This burial ground was established in 1853 by Charity Hospital in response to the overwhelming epidemics that swept the city annually during the 19th century. Interments were made there until 1929. The remains of more than 270 individuals were relocated from sections of this burial ground in 1986 prior to widening Canal Boulevard. Burial 56a, an African American male who was 35 to 45 years old at death, was found with a lead ball lodged in the neural arch of a thoracic vertebra (T3–T8). Fired from behind, the ball had penetrated the spinal canal and was embedded in the left half of the arch, breaking the left rib as well. Bone remodeling around the wound indicated healing and survival for numerous years (Owsley et al. 1990:115–119). Neither this man’s identity nor cause of death could be determined. A second individual from this cemetery also presented a gunshot wound: Burial 134b was a male (aged 25–35) of unknown ancestry who had suffered a perimortem gunshot wound to his right femur followed by amputation just above the knee. Metal fragments from the projectile were identified through radiographs in the remaining proximal portion of the femur (Owsley et al. 1990:119). The absence of healing indicated death quickly after the wound had occurred. The specific dates of these two interments remain undetermined.

Two historic period burials from different areas of New England also exhibited osteological evidence of gunshot wounds, although the second case remains inconclusive. The Luther Burial Ground, used between 1853 and 1936, was located in Johnston, Rhode Island, just a few miles west of Providence. A team of archaeologists and physical anthropologists excavated the site in 1997 prior to expansion of Rhode Island’s Central Landfill (Garman et al. 2000). One individual (Burial 88-9), Calvin Luther, Jr., presented a pseudoarthrosis (a false joint subsequent to a nonunited fracture) of two right ribs that most likely resulted from a gunshot wound. The right second and third ribs were united by two bony extensions that bridged the intercostal space just anterior to the facets where the ribs articulate with the second and third thoracic vertebrae (Figure 9)—an unusual location for a fracture and not likely caused by another type of trauma (Garman et al. 2000:212). Although the reburial schedule precluded radiographs of these ribs, the lesion was virtually identical to documented rib fractures that had healed subsequent to gunshot wounds in individuals from both 19th-century military skeletal collections and modern forensic cases. Luther was a Civil War veteran who served in the Fifth Rhode Island Heavy Artillery, Company K. He was detached from the service on account of “sickness” on 26 June 1865, 10 years before his death at age 53 from typhoid fever. Whether the injury to his thorax was related to his army service is currently unknown, but the degree of remodeling suggests that the injury had occurred at least several years prior to death.
Another gunshot wound possibly suffered in battle may not have been a gunshot at all. In September 1977, the National Park Service’s Boston office received a gift of several historical items from the Old South Meeting House, a former Puritan Meeting that currently operates as a museum. National Park Service accession records report that among the donated materials was a “rosewood box with glass window inset in cover and key—containing skull, bones, teeth, buttons, etc” (Accession No. BNHP 07). Apparently in the collection of the Old South Meeting House since at least 1876, the bones were alleged to represent the remains of a Revolutionary War patriot who had died during the Battle of Bunker Hill on 17 June 1775. The director of the Old South Meeting House informed Park Service staff members in 1977 that the remains were “collected in 1876 for the Centennial” by a Mr. William Wheildon. Indeed, the accession records note that the remains were “dug up near the corner of Elm and Bunker Hill Streets, at the base of Bunker Hill and near the rail fence, where the Great Battle of the day was fought.” Three musket balls also in the box were reportedly associated with the skeletal remains, including one badly deformed ball carrying the label “Fatal Bullet.” A large unhealed defect in the anterior portion of the cranium, which was held together by ancient masking tape, seemed to support that interpretation (Figure 10).

In 1998, Boston National Historical Park requested an examination of the remains in preparation for the 225th anniversary of the battle (on 17 June 2000). Based on both morphological and metrical analyses, the individual represented by the remains was a male of European descent who was 25 to 30 years of age at death (Crist 1999). The general appearance of the bones, degree of dental attrition, and level of fragmentation were consistent with skeletal remains dating to the historic period. The gross appearance of the remains, however, could not conclusively support or, conversely, exclude the possibility that this individual died during the last quarter of the 18th century.

No perimortem trauma was present. Anecdotal evidence suggested that defects of the calvarium resulted from a gunshot wound that had killed the individual during the Battle of Bunker Hill in 1775. The damaged cranial bones, however, presented clear color differentiation between the intact inner and outer tables and the exposed diploic space, indicating that the fractures had occurred during the postmortem period. No beveling or fracture lines of the types typically associated with gunshot wounds were present in any part of the cranial vault. Due to both the postmortem damage to the cranial vault and lack of documented provenience for the lead balls (the “chain of custody” in police parlance), the deformed ball was unlikely to have been the agent of death unless it had struck some other portion of the man’s body. While the skeletal remains may have represented an individual possibly consistent with the general demographic profile of a Continental soldier, the results of the forensic analysis could not support the assertion that the remains were those of a patriot killed at the Battle of Bunker Hill.

Osteological evidence of firearms deaths in the western United States is much more prevalent than among individuals buried in eastern cemeteries. While violence between Native Americans and western settlers and U.S. soldiers accounted for most of the stories in the eastern press after the Civil War, Americans of both European and African descent also fell victim to frontier gun violence at each other’s hands. Lane’s (1997:171) unequivocal rejection of the legend of western gunfights notwithstanding, violence was a definite part of frontier life and guns certainly were used to resolve personal conflicts. For instance, Anne Fox (1984) reports that 3 of 34 historic period burials excavated at
Choke Canyon Reservoir in Texas were victims of gunshot wounds (Table 1). Martin Luther Taylor and his son-in-law William B. Morris were allegedly killed and buried together in 1869 as part of the Taylor-Sutton Feud that raged through south Texas during the 1860s and 1870s (Fox 1984:9–14). The third gunshot fatality, discovered in the Yarbrough Bend Cemetery on the Edna Henry Ranch, was John Swanson Yarbrough, a veteran of the Army of the Republic of Texas who was shot to death in 1862 at the age of 88 in an argument with a horse trader (Fox 1984:22).

Excavations of the Seven Rivers Cemetery along the Pecos River in New Mexico in advance of a reservoir construction project provide osteological evidence to support Keleher’s (1957) and Clare McKanna’s (1997) conclusions regarding firearms violence in the New Mexico Territory. Of the 17 adult males buried in the graveyard, all from the late 1870s to ca. 1890, 8 presented gunshot wounds (Ferguson 1993). Based on the remains of projectiles found in the graves, two of these eight victims had died of shotgun blasts, two from rifle fire, and the other four men from .44 or .45 caliber bullets fired by pistols or revolvers (Ferguson 1993: [4]63; [5]27–28). The youngest victims were two men about 17 to 22 years old at death, three were 23 to 35 years old, two were 36 to 45 years old, and one was a young man of undetermined age (Table 1). None of the seven adult females buried at the cemetery presented evidence of gunshot wounds.

Contemporaneous newspaper accounts of the murder of one of the men, James Barnes (most likely Burial 42), provide a graphic illustration of Keleher’s (1957) description of the often-fatal results that ensued when alcohol and guns were mixed in the Old West. After a night of copious whiskey consumption in July 1893, one James Barrett shot fellow laborer Barnes to death in his tent at the Seven Rivers Dam tent camp (Ferguson 1993: [4]187–190). Ironically, it was Barnes who had given Barrett more whiskey to drink at two o’clock that morning, only to be killed an hour later for no apparent reason. Barrett was captured the next day by the local sheriff after a posse was dispatched to find him, had to be transferred to another jail to escape lynching by angry laborers at the camp, was found guilty of Barnes’s murder at a trial the following March, and was hanged on 14 September 1894. Reminiscent of the plots of numerous Hollywood westerns, James Barnes’s tale represents in microcosm the nature of gun violence and western frontier justice in the late-19th century. In a true case of life imitating art, bioarchaeology at Seven Rivers authenticates the cinematic perception that death by gunfire was a significant component of frontier life, especially among people on the economic margins of western society.

Twenty years earlier and hundreds of miles north of New Mexico, another pioneer had fallen victim to firearms violence. Researchers (Gill et al. 1984; Gill 1994:167–168) describe the skeleton of an unidentified white male shot to death in 1869 or 1870 and then buried among 12 historic period Plains Indians near the Bordeaux Trading Post, formerly located along the Oregon Trail in southeastern Wyoming. Buried with boots on his feet and a large-brimmed black felt hat covering his face, this man (aged 31–37) had sustained multiple .45 caliber gunshot wounds, including one that had shattered his left proximal femur and a second fatal shot to the forehead just above the left orbit. By tracing the trajectory of the projectiles and applying modern ballistics analyses, the investigators determined that the most likely sequence of events began with a gunshot to the victim’s left hip that knocked him to the ground, followed by a second shot through his head fired at close range (Gill et al. 1984: 235; Gill 1994:168).

Conversely, human remains from other western sites often can be clearly associated with specific historical events. Pioneers making their way westward toward California were all too familiar with the risk of death, especially if they suffered the ill luck of being trapped in the mountains as winter weather moved in. For 120 men, women, and children from Arkansas passing through Utah Territory in early fall 1857, it was not severe weather that took their lives but rather gunfire and beatings administered in one of the country’s worst cases
of mass murder (Novak and Kopp 2003). The emigrants unfortunately arrived in Utah on the cusp of hostilities between the U.S. Army, dispatched by President James Buchanan to replace Brigham Young as territorial governor, and Mormon forces preparing to defend their new Zion in the western frontier. On 7 September 1857, the emigrants' wagon train was attacked at Mountain Meadows, about 300 miles southwest of Salt Lake City. Four days later, the wagon party surrendered and the survivors of the initial attack marched in procession out of their compound. Upon reaching a clearing in the meadow, the Mormon militiamen shot each male emigrant while others, possibly Mormons disguised as Paiute Indians, beat the women and children to death.

During repair of a monument to the victims in 1999, workers unearthed the commingled, partial remains of at least 28 individuals. Of these, eight individuals presented evidence of gunshot wounds, all among their crania (Novak and Kopp 2003:90). Included among these eight victims was a teenager about 10 to 15 years old, possibly female, the only historic period subadult gunshot fatality reported thus far in the archaeological literature. The recovery of the remains from Mountain Meadows reopened a painful and very controversial chapter of western settlement, bringing to light new information about a tragically compelling incident little remembered outside of Utah. Indeed, until the remains were inadvertently discovered in 1999 only documentary sources were available to reconstruct the event, “sources that were based in many cases on the coached testimony of killers, hearsay of second parties, or the depositions of young children. ... More importantly, the skeletal evidence is qualitatively different from the oral accounts because the bones have not been affected by self-interested rhetoric or shifting political winds” (Novak and Kopp 2003:104).

Unlike the little-known saga of the Mountain Meadows massacre, the violent life-and-death story of another historic period figure whose remains were excavated by bioarchaeologists is well known in American popular culture, to the extent that his story was even featured in an episode of the *Brady Bunch* television series. (Episode 87, “Bobby’s Hero,” originally aired on 2 February 1973.) The notorious western outlaw Jesse James was reportedly shot to death at age 34 in St. Joseph, Missouri on 3 April 1882 and buried three days later at the James’s family farm near Kearney, Missouri (Finnegan and Kysar 1998). In 1902, skeletal remains thought to be his were exhumed and reburied next to his wife, Zerelda, in the Mount Olivet Cemetery in Kearney. Several legends stating that James had escaped the gunfire in 1882 and actually died in the early 1900s had arisen in the intervening years. In July 1995 court permission was granted for a scientific team to excavate the alleged grave of Jesse James in Mount Olivet Cemetery and conduct a complete forensic analysis of the remains buried there. Although the cranium was fragmented and had been subjected to an autopsy cut through the calvarium, forensic anthropologists identified one projectile entrance wound consistent in size with that of a .45 caliber ball in the occipital. In 1978, a .45 caliber ball had been recovered during excavations of James’s original grave shaft at the former James farm, providing independent corroboration of the osteological interpretations. Based on the overwhelming correlations between the forensic anthropological results and the historically documented attributes of Jesse James, as well as the results of mitochondrial DNA analysis, the scientific team concluded “within reasonable scientific certainty” that Jesse James was, in fact, shot and killed in April 1882 and reburied in his final resting place next to his wife 20 years later (Finnegan and Kysar 1998:545).

Although a minor outlaw in comparison to Jesse James, a train robber killed by gunfire in 1911 almost became as famous six decades later, courtesy of television’s *Six Million Dollar Man* action series. In an entertaining account, Clyde Snow and Theodore Reyman (1984) describe how, in 1976, a television crew from the popular program, filming on location at Nupike Amusement Park in Long Beach, California, discovered Oklahoma bandit Elmer J. McCurdy’s embalmed remains hanging from a gallows in a funhouse when his arm fell off as they tried to move him for a better shot. A posse had killed the 31-year-old McCurdy in a barn near Pawhuska, Oklahoma, two days after he and his gang had ambushed a train they mistakenly thought was carrying tribal payments. According to a contemporary newspaper account, he
was killed during a shootout with three men, hit in the thorax by one .32-20 caliber bullet. The local funeral director heavily embalmed McCurdy using an arsenic-based preservative and promptly put his corpse on display until about 1916, charging patrons a nickel to view the "bandit who wouldn’t give up." Over the next 60 years, McCurdy’s body was sold to a successive chain of carnivals, wax museums, and haunted houses, including one near Mount Rushmore that rejected him because the proprietor thought he was a mannequin that was not sufficiently lifelike (Snow and Reyman 1984:375).

The forensic anthropological examination of McCurdy’s remains in 1976 revealed incisions from the autopsy and subsequent embalming as well as a gunshot entrance wound in the right anterior chest. A copper bullet jacket or gas check from a .32-20 projectile was embedded in the pelvis; analysis indicated that the jacket was manufactured between 1905 and the late 1930s. Embalming with arsenic was prohibited by most states after 1920, providing a more specific date range for the year of death. Finally, video superimposition of the remains from the funhouse with photographs of McCurdy’s corpse curated at the University of Oklahoma’s Western History Collection confirmed his identity. McCurdy’s remains were returned to Oklahoma in April 1977, and he was buried the following week in the Summit View Cemetery at Guthrie. The State Medical Examiner ordered two cubic yards of concrete poured over McCurdy’s new casket, permanently ending his career in show business.

Bioarchaeologists have resolved other mysteries surrounding western homicides. Ironically, it was the sale of land in Las Vegas, Nevada, to a mortuary for expansion of a parking lot that led to the excavation of the remains of Archibald Stewart, Sr. (Brooks and Brooks 1984:69–74). In the 1880s, Stewart was the owner of the Las Vegas Ranch, which his wife Helen ran as a rest stop for travelers passing through the southern Nevada desert (Crosby 2002). In summer 1884, a ranch worker named Schuyler Henry quit the Las Vegas Ranch and apparently began spreading rumors about Helen Stewart that offended her husband, Archibald, then 49 years old. On 13 July 1884, Archibald Stewart rode to the neighboring Kiel Ranch, allegedly armed with a rifle, to settle the score with Henry. According to Henry’s later testimony, Stewart shot first and Henry returned fire with a shotgun, hitting Stewart in the chest. Stewart’s second shot hit Henry in the hip, and Henry’s return volley struck Stewart in the head, killing him. Helen Stewart maintained afterwards that her husband had been ambushed by the owner of the Kiel Ranch together with Henry and a gunfighter named Hank Parish, but a grand jury refused to indict any of the men on murder charges even though some witnesses claimed that Stewart’s chest wound had been caused by a pistol, not a shotgun as Henry had maintained (Crosby 2002).

The examination of Archibald Stewart’s remains revealed that his right zygomatic and maxilla had been broken away, and the entire posterior portion of his cranium was missing. Sheilagh Brooks and Richard Brooks (1984:71) concluded that Stewart “had been killed by a shot into his right cheek, which had exited through the back of the skull.” Although no projectile was found in the grave to confirm Henry’s account that he had defended himself with a shotgun, the forensic examination of Stewart’s remains corroborated at least part of Henry’s testimony and proved that Stewart had not been shot in the back.

This tragic story does not end there. In 1975, Brooks and Brooks (1984:74–83) also conducted the relocation of burials from the former Kiel Ranch, including the remains of brothers Edwin and William Kiel. Local legend had it that in 1900 Edwin had killed William with a shotgun and then committed suicide with a handgun. Their bodies, strangely enough, were found by members of the Stewart family on or near the Stewart Ranch (Crosby 2002). Given Archibald Stewart’s gunshot death on the Kiel Ranch in 1884, questions naturally arose regarding the accuracy of the interpretations of the Kiel brothers’ deaths. A coroner’s inquest, however, accepted the alleged events as reported.

Examination of the remains of both Kiel brothers revealed that William had been shot at least twice with a shotgun, shattering his left radius and ulna and severely fracturing his cranium (Brooks and Brooks 1984:81–82). A .45-caliber entrance wound was present in Edwin’s occipital, just behind and below his left ear. His facial bones had been destroyed by the exiting projectile. Based on the nature and positions of the entrance wounds, Brooks and Brooks (1984:82)
concluded that the Kiel brothers had died in an ambush perpetrated by others, not as the result of fratricide and suicide.

The African American presence on the 19th-century western frontier was as pervasive as it is undocumented. Free African Americans worked as ranch hands and cowboys; enslaved individuals were brought to the West by plantation owners who established farms and trading posts. Whether free or enslaved, African Americans were not immune to western gun violence.

The remains of one African American individual were discovered in 1980 beneath the floor of a building at the former Rock Ranch, located near Torrington, Wyoming (Gill 1987; 1994:166–167). This man, 24 to 30 years old at death, had died from at least three gunshot wounds, two to the head and one to the lower back. A .44 caliber bullet was found embedded in the man’s third lumbar vertebra, but projectiles of two different sizes apparently caused the other wounds. According to local legends, an enslaved African American man brought to the trading post in the 1850s had been killed there and buried under the floor of one of the buildings. Gill’s findings (1987; 1994:167) confirmed the story, adding to it the likelihood, based on the osteological evidence, that the unnamed man was ambushed by at least two others brandishing three different guns. It appeared that the final round had entered the man’s head right between his eyes.

Interest in the nature of violence and its social consequences during the historic period is not confined to historians, forensic anthropologists, and sleuths interested in historical mysteries. Coincidentally, at the same conference during which this study was first presented, archaeologist James M. Davidson (2003) delivered a paper in which he addressed historic period gun violence as reflected through the remains of gunshot victims discovered in the early 20th-century Freedman’s Cemetery in Dallas, Texas. Freedman’s Cemetery was the primary burial ground for Dallas’ African American community between 1869 and 1907 (Condon et al. 1998; Davidson 2004). Due to a major highway expansion, the Texas Department of Transportation sponsored the archaeological excavation of 1,157 individuals from the former cemetery.

Researching the stories of 18 African Americans who had been interred in Freedman’s Cemetery between 1900 and 1907 and who presented unmistakable evidence of fatal gunshot wounds, Davidson explored the causes of gun violence in the early-20th century, especially as it affected Dallas’ African American community. By focusing on gun violence among African Americans, this particular study provides another unique dimension to the study of the American gun culture in that homicides among nonwhite social groups were poorly recorded, if even acknowledged, in official statistics until the 1930s (Lane 1997:310). As demonstrated by Davidson’s paper, bioarchaeology provides a method to trace the origins and nature of violence in historic period minority communities, providing data truly unavailable from documentary sources.

**Discussion and Conclusion**

This book does not argue that guns did not exist in early America, nor that gun violence did not occur. . . . This book is concerned with the normative, with what most people did, owned, and thought in reference to guns, most of the time [emphasis in original].


One of historical archaeology’s missions is to illuminate what the past was like for most of the people, most of the time. Historical archaeologists share with historians a unique perspective based on time depth that allows them to examine current issues through the lens of accumulated social experience. Unlike most historians, however, archaeologists are as interested in the material culture of the past as they are in documentary evidence. This includes the actual remains of the people of interest, a source of information that equips archaeologists to enter debates of relevance to society as more insightful commentators.

The question of personal gun ownership during the early history of what is now the United States lies at the root of the modern argument between supporters of gun control and those whose interpretation of the Second Amendment endows private citizens with the right to keep and bear arms. As Lane (1997: 343) complains, “Neither side resorts to the historical evidence, although both might score points if they used it selectively.”

The documentary evidence is, at least, ambiguous. Growing gun ownership during
the colonial period did not drive up the national homicide rate; conversely, after the 1830s an ever-increasing number of homicides have resulted from gunfire, particularly in the large cities. The West was always dangerous, especially after the Civil War. Accidental firearms deaths must also be addressed as part of the debate: “The high number of gunshot accidents resulting from stashed weapons in the home, many of them fatal to young children, is unique to [the United States]” (Lane 1997:347). Lane (1997:346–348) notes that historical experience demonstrates prohibition of gun sales generally restricts only hunters and noncriminals from acquiring handguns.

Into the middle of this interminable minefield of a contest tread the historians of America but, as of yet, virtually no archaeologists or bioarchaeologists. As a group devoted to reconstructing the U.S. past as accurately as possible, archaeologists have a great deal to contribute. Although Bellesiles failed to incorporate archaeological data into his research, the results from this preliminary survey of gunshot victims reported in the archaeological literature, which emphasizes the relatively rare occurrence of projectile trauma among pre-1850s burials, may provide tentative support for his interpretations regarding the lack of firearms use in colonial America. Much larger samples of 18th-century burials will be needed before conclusive bioarchaeological evidence is secured.

Bioarchaeological data do support the pervasive nature of violence in the Old West described by Kelcher (1957), McKenna (1997), and others. Although many were excavated precisely because of their association with gun violence, archaeologists in the western states have identified a comparatively large number of postbellum gunshot victims. Relatively cheap, mass-produced handguns clearly fueled a wave of violence across the West influenced and propagated largely by a dangerous mix of demographic trends, economic pressures, and social instability. Samuel Colt would have approved: his guns equalized the chances for anyone to die of a gunshot wound following even the most minor offense.

There currently exists a relatively small sample of historic period human remains that have been or are available for anthropological study, at least compared to the cumulative American population buried across the nation. Yet, systematic recordation of the nature and locations of gunshot wounds among even this tiny sample, taken from a variety of temporal and geographic contexts, provides data unavailable from archival materials about the actual frequency of firearms violence among population subgroups not counted in official records, particularly minority groups, women, and children. These data allow more focused, critical assessments of conclusions, such as those drawn in *Arming America* and other studies of gun violence in the past, hopefully minimizing the political and emotional static that often obscures the facts in the ongoing argument over personal gun ownership and gun control in today’s society.

In his precontroversy review of *Arming America* for the *Journal of American History*, Lane (2001:614) wrote, “[Bellesiles] makes it clear from the opening, a hostile description of the contemporary gun culture, that he intends to have an impact on public policy or at least discourse.” Archaeologists have much to add to this particular debate, and our collective voice should not be silent.

**Acknowledgments**

I would like to thank Julie Schablitsky for asking me to participate in the session “Remains of the Day: Forensic Applications in Archaeology” at the 2003 SHA conference and for giving me the opportunity to publish this paper. I am indebted to my friend and mentor Ted A. Rathbun, professor emeritus at the University of South Carolina, whose seminal book on case studies in forensic anthropology introduced me as a graduate student to the topic of gunshot wounds among historic period human remains. I also appreciate the opportunities I had to work on so many interesting and significant projects and the support given me by the principals at John Milner Associates, Inc., and Kise Straw and Kolodner, Inc., particularly Daniel G. Roberts and Patrick W. O’Bannon. I must also thank our clients, especially the National Park Service and Public Archaeology Laboratory, Inc., and my many friends and colleagues without whom none of these projects would have been realized. I thank Douglas D. Scott for sending me copies...
of George W. Gill’s articles on western gunshot victims, to J. Homer Thiel of Desert Archaeology in Tucson for sending me the invaluable Seven Rivers Cemetery report, and to Douglas W. Owsley for providing me with information on the two gunshot victims he identified among the remains from the Charity Hospital/Cypress Grove II Cemetery. This paper benefited greatly from the comments on ballistics provided by William Stevens and input from Molly Hickey Crist, my wife and partner. I wish to thank Julie H. Ernstein and the two anonymous reviewers whose comments and suggestions assisted me in reassessing and improving this paper. I appreciate the ongoing support for my work from K. Della Ferguson and Dale L. Scalise-Smith and would also like to acknowledge the financial support to attend the 2003 SHA conference provided through a Faculty Leadership Grant from Utica College. The opinions and statements included in this paper are mine alone and do not necessarily represent those of my employers or colleagues, past or present.

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